Herança -History, Heritage and Culture Journal
2026, 9(1), 109-132
ISSN: 2184-3090
https://revistaheranca.com
Research Article

Use of Wood in the Construction Tradition of a 17th-Century Church in Southern Brazil

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Citation: Andrade, E. K., & Melo Júnior, J. C. F.(2026).Use of wood in the construction tradition of a 17th-century church in southern Brazil. *Herança*, *9*(1), 109-132. https://doi.org/10.52152/heranca.v9i1/1201

ARTICLE INFO

Received: 12 Oct 2025
Accepted: 14 Jan 2026

ABSTRACT

Wood has been one of the oldest and most widely used building materials throughout history. During the colonial period in Brazil, woodwork ranged from artistic expression to the construction of edifices that represented the formation of new settlements, such as religious temples. This study aimed to understand the use of wood as a construction technique and structural solution in the Church of Nossa Senhora da Graça, located in southern Brazil, by analyzing the wood used in this historical building. The research followed the assumptions of historical anatomy, beginning with the survey of documentary sources on the history of the city and the church. Wood samples were obtained from all the church's structural components, along with photographic and floor-plan records of the building. Histological preparations were prepared according to standard wood anatomy techniques and subsequently used for structural description and taxonomic identification based on a reference collection. In the original structure, eight native arboreal taxa from the Atlantic Forest with natural occurrence in southern Brazil were identified. The predominant wood used in the roof structure, bell tower staircase, and flooring is Ocotea porosa -Lauraceae (imbuia). The replaced truss piece was made of Licaria sp. -Lauraceae (louro). The frames were entirely constructed from Handroanthus sp. -Bignoniaceae (ipê). Internal structures, such as staircases, were made from Cedrela sp. -Meliaceae (cedro). In the wattle-and-daub wall framework, Ocotea sp. -Lauraceae (canela) was found. The central pillar supporting the bell tower staircase is Calophyllum brasiliense -Calophyllaceae (olandi), and the steps of the same staircase were composed of Aspidosperma sp. -Apocynaceae (peroba). The wooden floorboards were made of Ocotea cf. cymbarum -Lauraceae (louro-mamoreim). All taxa naturally occur in the Atlantic Forest, except Licaria sp. and O. cymbarum. All taxa exhibit high density and resistance to decay and insect attack, compatible with their use in construction. The use of Licaria sp. showed interventions carried out over time to maintain the building's functionality, in accordance with the Venice Charter. It was thus possible to understand the link between construction techniques and the use of wood in this building, contributing to the preservation and appreciation of historical heritage, while highlighting wood as an essential cultural and historical element in colonial architecture.

Keywords: Historical Woods; Wood Heritage; Wood Anatomy; Cultural Heritage; Traditional Carpentry.

INTRODUCTION

Wood is one of the most important renewable raw materials and the most widely used resource worldwide-for tools, fuel, weapons, structures, and recreation—by human cultures for thousands of years. The multiple uses of wood as a fundamental raw material have driven human development and shaped the way of life of all societies. Its varied colors, textures, aromas, and densities make wood extremely versatile in terms of applicability, resulting in the production of cultural goods that represent different cultures and convey identity (Melo Júnior, 2024).

In Brazil, traditional construction has long regarded wood as its most valuable material. During the colonial period, woodwork ranged from elaborate artistic expression to the construction of houses for the lower classes (Boschetti, 2010). The appreciation of wood as a structural element varied over time. The abundance of wood in forests was a decisive factor, often influencing the level of skill developed by each culture in shaping components and improving joinery through the creation of specific tools and construction techniques (Melo Júnior, 2016).

ety and properties of the species available in nature. This knowledge, intertwined with the history of Santa Catarina and Brazil itself, underscores the cultural importance of wood in the construction of built heritage, as this resource has always been present in history and has contributed to societal development (Melo Júnior, 2017). This expertise, embedded in the historical context of Santa Catarina and Brazil, highlights wood as an essential element in the construction of cultural heritage, linking natural resources to the history and culture of different peoples.

Based on these considerations, this article aims to analyze and understand the use of wood as a constructive technique and structural solution in a 17th-ceUnderstanding the use of each type of wood derives not only from accumulated knowledge about forests over many generations but also from the exchange of information among different traditional communities that have encoded and decoded the forest throughout history. These communities relied on their own classification systems based on popular knowledge, gradually building through trial and error a systematic technological understanding that enabled them to manage forest resources with precision and sustainability (Melo Júnior, 2021).

In church construction — particularly Catholic churches — the form and scale of buildings were often more significant than the materials used. Most were built of stone with wooden roofing structures (Silva, 2019). In such edifices, wood played a fundamental role, whether as a structural element (roofs, staircases, and pillars), as finishing material, or in the composition of furniture and statuary. For many centuries, the Church and architecture developed in symbiosis, allowing both to evolve exponentially (Silva, 2019). Indeed, the greatest architectural works in human history are mostly churches (Silva, 2019), including renowned examples such as the Notre-Dame Cathedral in Paris, the Duomo of Florence, and St. Peter's Basilica—the largest and most important Catholic building in the world (Silva, 2019).

Similarly, in Brazil, Catholic churches reached their peak during the colonial period, profoundly shaping both urban and rural landscapes. The Church's presence was constant throughout Brazil's colonization, at various scales and forms — from the earliest expeditions to the continent to later incursions into the hinterlands in search of precious metals (Vasconcellos, 2018).

The Mother Church of Nossa Senhora da Graça, in São Francisco do Sul, SC, built between 1658 and 1665 in Venetian style, is the oldest in Santa Catarina and the third oldest sanctuary in Brazil. Listed by IPHAN in 1987, it stands as an icon of the city's Cultural Heritage, alongside more than 400 historic buildings (Amorim, 2020). Despite its historical, architectural, and religious relevance, there remain gaps in knowledge regarding the materials, constructive techniques, and architectural evolution of the building. This lack of detailed information compromises both the full appreciation of the monument and its conservation and restoration. Comprehensive research is therefore essential to enhance historical understanding, valorize the heritage, and guide preservation efforts.

The historical use of wood demonstrates humanity's knowledge of the varintury historical building in southern Brazil, seeking to comprehend its historical and cultural significance within the construction tradition.

MATERIALS AND METHODS

The Historical Building Studied

In 1504, the French navigator Binot Paulmier de Gonneville, commander of the expedition that had departed from France the previous year, landed on the beaches of Babitonga Bay as shown in Figure 1. At this site, the French coexisted for several months with the Carijó Indigenous people, natives of the region. More than a century later, in 1641, Gabriel de Lara—mayor and capitão-mor of the town of Nossa Senhora do Rosário in the Captaincy of Paranaguá—founded the settlement of Nossa Senhora da Graça do Rio São Francisco. Seventeen years after the foundation of the settlement, in 1658, the construction of the church began, which was completed seven years later, in 1665 (IPHAN, 2014).

Figure 1. Location of the Mother Church of Nossa Senhora da Graça, Historic Center of São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: A -Location of São Francisco do Sul in Brazil and in Santa Catarina. B -Location of the Historic Center. C -Historic Center. D -Current façade of the Mother Church of Nossa Senhora da Graça.

The church, together with about 400 other properties, is part of the ensemble of the Historic Center of São Francisco do Sul, which was listed by the Instituto do Patrimônio Histórico e Artístico Nacional (IPHAN) in 1987. This area includes the city's original nucleus, the surrounding ridges, and the maritime shoreline. The listed heritage comprises colonial-style houses, shell mounds (sambaquis), old churches, and approximately 150 houses and monuments. Within the urban complex are the civic and religious centers, around which commerce and services are concentrated (IPHAN, 2014).

According to documents provided by IPHAN, the church underwent several restoration projects, notably a major revitalization carried out under the Monumenta Project, a partnership between the Municipal Government and the Federal Government in the early 2000s. This project promoted the restoration of wooden structures, plaster, improvements to the electrical system, and both interior and exterior painting. Currently, the structure and façade are well preserved and in good condition. The white paint with yellow details that accentuate the architectural outlines reflects the colonial period in which the church was built.

Architectural Survey of the Building

The Mother Church of Nossa Senhora da Graça and its surroundings are nationally listed by IPHAN; therefore, the analysis of official correspondence and technical opinions from the institution was required. All documentation is preserved at IPHAN's headquarters, located in the historic center of São Francisco do Sul, where the church itself is situated.

Documentary research was conducted to access the original architectural plans, the listing process, and restoration records. Field inspections and photographic documentation were also carried out to map the locations of wooden structures and to collect samples from all constructive elements made of wood.

Before this inspection, documentary and iconographic research was undertaken to understand the building, including: existing architectural plans and structural schemes; historical records and published materials; and interviews with historians, restorers, or individuals responsible for the property. These primary sources were obtained at the IPHAN office, located in the Historic Center of São Francisco do Sul, Santa Catarina State, the same area where the Mother Church is located.

The identification of structures and constructive elements was performed through measurement processes. According to the technical guidelines of the Monumenta Project, these processes employ a wide range of instruments, many of which have been used since antiquity, such as rigid and folding scales, measuring tapes, theodolites, staffs, levels, clinometers, goniometers, compasses, and plumb lines. In addition, modern technologies such as photogrammetry and computational tools for image rectification expand the possibilities of documentation and structural analysis, ensuring greater precision in the representation of architectural elements (Brasil, 2005).

On-site inspection was conducted to identify and record wooden structures, following the procedures specified in the technical manual of the Monumenta Project (Brasil, 2005) concerning architectural surveys and documentation:

a. preliminary recognition of the monument -included access assessment and identification of points for wood sampling in the structure;

b. preliminary photographic coverage -to facilitate evaluation of the overall building ensemble;

c. review of texts and iconographic material -to aid the reconstruction of the building's history and support the cognitive phase of the study;

d. final drafting in AutoCAD -the plan was provided by IPHAN, but required digital reproduction for analytical use.

For mapping the wooden structures, the architectural drawings and schematic plans were annotated to indicate the areas containing timber, distinguishing elements such as beams, rafters, floors, ceilings, and frames. In the photographic documentation, detailed images of the wooden components were obtained, including general views and close-ups showing joinery, deterioration, and signs of previous interventions.

According to the Monumenta Project, photographic recording is an essential documentation tool that supports survey work and allows, through image rectification, the generation of reliable geometric data (terrestrial or short-distance photogrammetry) (Brasil, 2005).

Sampling and Wood Analysis Procedures

Sample collection followed a protocol designed to minimize impacts on the structure. According to IPHAN guidelines, the sampling sites and collected specimens must be mapped and indicated in photographs and/or drawings. Samples were taken from discreet locations, preferably outside the main visual areas of the elements, with minimal intervention as a guiding principle (IPHAN, 2018).

Appropriate tools such as scalpels, hole saws, or Pressler borers were used to remove small fragments without compromising the integrity of the architectural elements. Each sample received an identification code containing precise location and type of structural element.

The wood samples were later used to determine the species and forest origin of the historical timbers employed in the church carpentry. All collections were authorized by national heritage protection agencies, including IPHAN and the Fundação Cultural de São Francisco do Sul. Authorization was also obtained from the Diocese of Joinville, responsible for the Parish of Nossa Senhora da Graça. The collected samples were deposited in the Joinville Wood Collection (JOIhw -Univille), as histological slides prepared according to the standard techniques in wood anatomy (Kraus & Arduin, 1997).

Samples were softened by boiling in a glycerin–water solution, and histological sections were made using a sliding microtome with C-type blades. The sections were then bleached with sodium hypochlorite, rinsed with distilled water, stained with safrablau (safranin + Astra blue), dehydrated through an ascending ethanol series, and fixed with butyl acetate under a fume hood (Kraus & Arduin, 1997). Mounting was performed using synthetic resin (vitreous varnish type) (Paiva et al., 2006).

Anatomical descriptions were made using an Olympus CX31 transmitted light optical microscope and followed the terminology established by the IAWA Committee (1989). Mineral inclusions were observed under polarized light using the same equipment, and photomicrographs were taken with an OPTICAM O600RT photomicroscope.The physical and mechanical properties of the identified woods were verified using specialized literature (Mainieri & Chimelo, 1989), taking into account species of greater importance value recorded in phytosociological surveys conducted in Santa Catarina (Vibrans, 2013), used as reference for taxa identified at the genus level. The classification proposed by Coradin et al. (2010) was adopted, considering low-density wood (< 0.550 g/cm³), medium-density wood (0.551–0.720 g/cm³), and high-density wood (> 0.721 g/cm³). Common and scientific names, geographical distribution data, and conservation status of the species were obtained from the Reflora biodiversity database (BFG, 2021).

Taxonomic identification was performed through comparative analysis, based on reference collections of the Joinvillea Wood Collection (JOIw) (Melo Júnior et al., 2014), as well as the InsideWood digital database (Wheeler, 2011) and specialized literature (Record & Hess, 1943; Détienne & Jacquet, 1983; Mainieri & Chimelo, 1989).

RESULTS AND DISCUSSION

Architecture of the Igreja Matriz Nossa Senhora da Graça

Originally conceived in Renaissance Venetian style, the church was built by enslaved people who used materials such as stone, lime, and oil in its construction. The roof structure is made of wood and has undergone several renovations over the years (Amorim, 2020). Initially, when the church was conceived in 1658, the project did not include any towers; during construction, only one tower was built, and over the years, the building underwent several modifications, including the construction of a second tower (Amorim, 2020) (Figure 2).

Figure 2. Temporal evolution of the façade of the Igreja Matriz Nossa Senhora da Graça, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: A -year 1665. B and F -year 1783. C -year 1926. D and G -1950. E -year 1965. H -Present day. Source: Historical archive, adapted by the author.the influence of Western architecture, put forward new requirements.

It is evident that even when the church had only one tower, changes were made to its façade, such as the addition of windows and other ornamental details (Figure 2C – D). The current façade, with two towers and constructive details (Figure 2E and H), represents the finalized version of the church after the restoration carried out in the second half of the 1960s.

The ground plan consists of a central nave, two lateral aisles, and the altar, as shown in Figure 3.

At the front sides are the towers, one of which houses the bell, accessed by a staircase. At the back are the parish office, the museum reception, the Father Fidelis room, and the sacristy, where the staircase leading to the second floor is located; this upper floor houses the Museum of Sacred Art. The walls are composed of stone structures with thicknesses varying from 0.70 to 1.20 m.

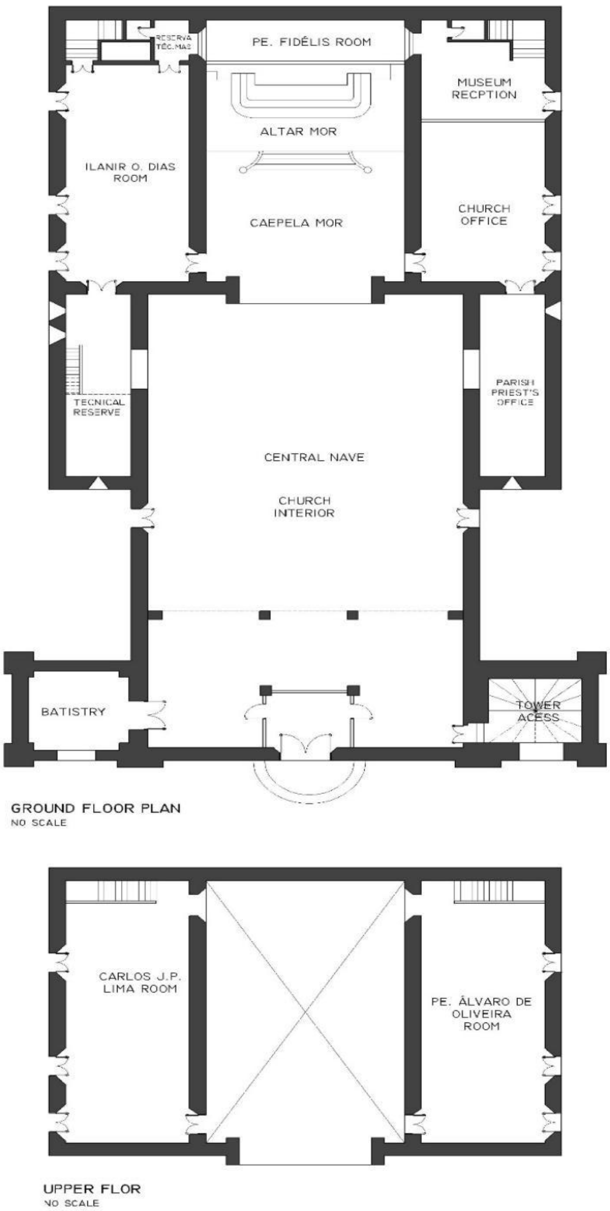

Figure 3. Ground and mezzanine floor plans of the Igreja Matriz Nossa Senhora da Graça, São Francisco do Sul, Santa Catarina State, Southern Brazil. Source: IPHAN archives, redrawn in AutoCAD by the author (2024).

Wood is present throughout the structure: in the roof framework, wooden flooring, stair structures, and window and door frames. In the roof structure, the wooden elements were cut at angles according to the roof slope and fitted together to form trusses that support the entire load of the structure. Differences in the age and condition of the wood are evident, as some parts were replaced during the restoration process. In the staircase structure located in the right tower, leading to the bell, both the supporting pillar and the steps were also made of wood.

In the central pillar of the staircase structure, more than one log was required, joined longitudinally through notching. This type of wood joinery has been used in traditional construction for centuries, ensuring stability without compromising structural strength. The joints between wooden elements are generally the most fragile points of wooden buildings, as they concentrate the greatest stresses, which can affect structural performance. However, the simplicity of wooden joinery has always been an advantage of this technique compared with concrete or steel (Lourenço & Branco, 2012). Wood is also present in the building's window and door frames, which are solid and robust due to their large dimensions.

Some internal walls that do not have structural functions, such as the wall leading to the sacristy, were built using the colonial taipa de mão technique. The taipa de mão walls (also regionally known as taipa de sebe, pau a pique, barro armado, taipa de pescoção, tapona, or sopapo) were widely used throughout Brazil since the beginning of colonization. The taipa de mão walls of the colonial period almost always formed part of a rigid wooden framework composed of posts, sill beams, plates, and upper and lower lintels. They served as partitions of independent structures or as interior walls within buildings whose exterior walls were made of taipa de pilão (rammed earth) (Pisani, 2004).

Constructive Woods of the Parish Church

Eight taxa were identified among the 23 structural wooden elements analyzed: Aspidosperma sp. (Apocynaceae -peroba), Calophyllum brasiliense Cambess (Calophyllaceae -olandi), Cedrela sp. (Meliaceae -cedro), Handroanthus sp. (Bignoniaceae -ipê), Licaria sp. (Lauraceae -louro), Ocotea cf. cymbarum (Nees & Mart.) Barroso (Lauraceae -louro-mamorim), Ocotea sp. (Lauraceae -canela), and Ocotea porosa (Nees & Mart.) Barroso (Lauraceae -imbuia).

The anatomical description of the wood, which enabled species identification, is presented below. Figure 4 shows the sampling points of the wooden elements, and Table 1 summarizes their physical and mechanical properties.

CODE	LOCATION OF SAMPLE COLLECTION	SPECIES
EKA01	Floorboard	Ocotea cymbarum (louro mamorim)
EKA02	Window frame – access to sacristy	Ocotea sp. (canela)
EKA03	Step below the sacristy stairs	Ocotea sp. (canela)
EKA04	Beam – wall below the stairs	Cedrela sp. (cedro)
EKA05	Rammed earth wall below the stairs	Ocotea (canela)
EKA06	Pillar below the stairs	Ocotea (canela)
EKA07	Wall/sacristy below the stairs	Cedrela sp. (cedro)
EKA08	Sacristy/museum floorboard	Ocotea (canela)
EKA09	Baluster – museum balustrade	Ocotea (canela)
EKA10	Sacristy window	Handroanthus (ipê)
EKA11	Bell base – beam	Handroanthus (ipê)
EKA12	Handrail – bell access	Ocotea (canela)
EKA13	Bell tower floorboard	Ocotea (canela)
EKA14	Central pillar of the bell tower stairs	Calophyllum brasiliense (guanandi)
EKA15	Bell tower structure	Ocotea (canela)
EKA16	Step – bell tower stairs	Aspidosperma sp. (peroba)
EKA17	Roof truss (new part)	Licaria (louro)
EKA18	Roof truss (old part)	Ocotea (canela)
EKA19	Mezzanine door	Handroanthus (ipê)
EKA20	Mezzanine floorboard	Ocotea cymbarum (louro mamorim)
EKA21	Sacristy rammed earth wall	Ocotea (canela)
EKA22	Main door	Handroanthus (ipê)

Figure 4. Ground-floor, mezzanine, and roof plans indicating the sampling points for wooden elements in the Igreja Matriz N Senhora da Graça, São Francisco do Sul, Santa Catarina State, Southern Brazil Source: IPHAN,

Source: Adapted by the author.

Growth ring: distinct, demarcated by fiber wall thickening and marginal bands of axial parenchyma.Vessels: diffuse-porous; solitary; tangential diameter ≤ 50 µm; frequency ≥ 100 vessels/mm²; length 350–800 µm; simple perforation plates; alternate, minute intervascular pits ≤ 4 µm; ray–vessel pits with distinct borders, similar in size and shape to intervascular pits; gum deposits present. Fibers: simple to minute pits; non-septate; thin- to thick-walled; length 900 – 1600 µm. Axial parenchyma: apotracheal diffuse and diffuse-in-aggregates; fusiform series with 3–4 to 5–8 cells. Rays: uniseriate, homogeneous; 4–12 rays/mm.

Aspidosperma sp. -Apocynaceae (Figure 5)

Growth ring: distinct, demarcated by fiber wall thickening and marginal bands of axial parenchyma.Vessels: diffuse-porous; solitary; tangential diameter ≤ 50 µm; frequency ≥ 100 vessels/mm²; length 350–800 µm; simple perforation plates; alternate, minute intervascular pits ≤ 4 µm; ray–vessel pits with distinct borders, similar in size and shape to intervascular pits; gum deposits present. Fibers: simple to minute pits; non-septate; thin- to thick-walled; length 900 – 1600 µm. Axial parenchyma: apotracheal diffuse and diffuse-in-aggregates; fusiform series with 3–4 to 5–8 cells. Rays: uniseriate, homogeneous; 4–12 rays/mm.

Figure 5. Constructive element and respective wood anatomy of Aspidosperma sp. (Apocynaceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Bell tower staircase steps. (B) Transverse section. (C) Radial longitudinal section. (D) Tangential longitudinal section.

Calophyllum brasiliense -Calophyllaceae (Figure 6)

Growth ring: indistinct. Vessels: diffuse-porous, arranged diagonally; solitary and in pairs; tangential diameter 100–200 µm; frequency 5–20 vessels/mm²; length ≤ 350 µm; simple perforation plates; alternate small intervascular pits (4 – 7 µm); ray – vessel pits apparently simple, with reduced, rounded, or angular borders; vasicentric tracheids present; tyloses common. Fibers: simple to minute pits; non-septate; thin- to thick-walled; 900 – 1600 µm long. Axial parenchyma: apotracheal diffuse, diffuse-in-aggregates, paratracheal aliform and confluent; fusiform series with 5 – 8 cells. Rays: 1 – 3-seriate, heterogeneous; ≥ 12 rays/mm. Prismatic crystals present in axial parenchyma chambers.

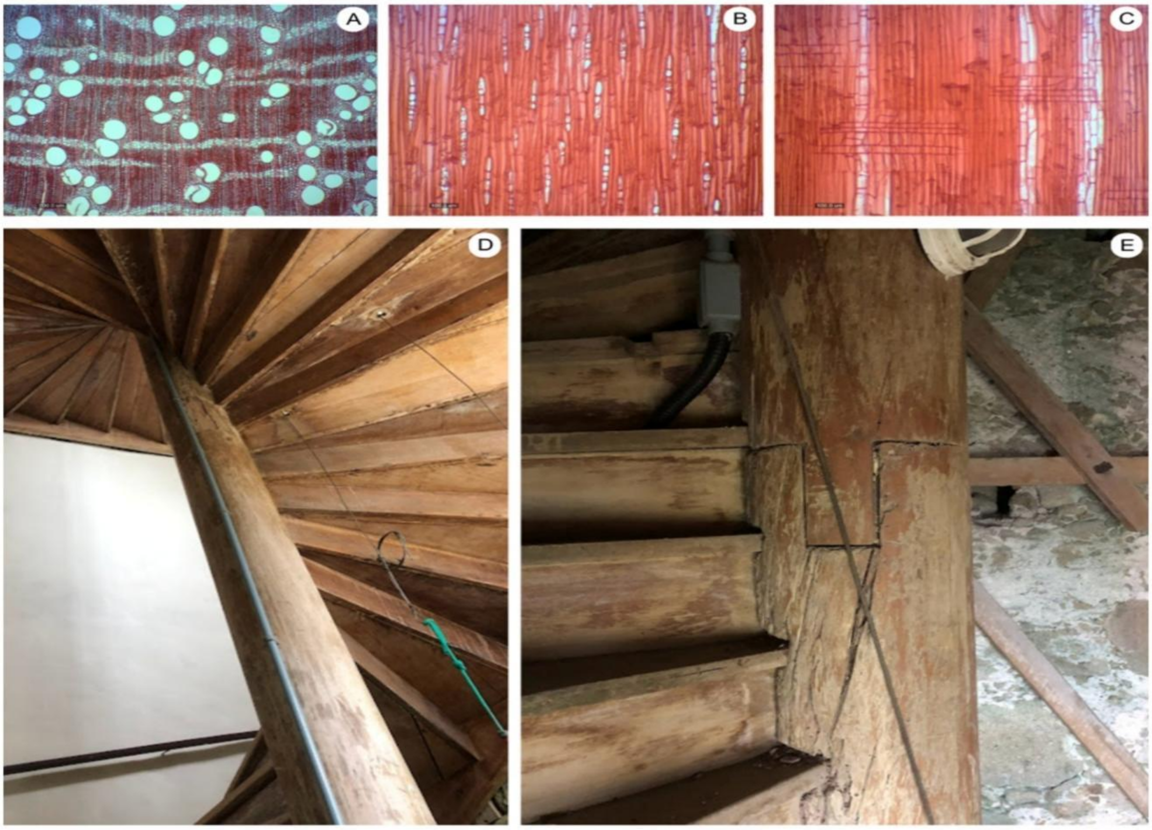

Figure 6. Constructive element and respective wood anatomy of Calophyllum brasiliense (Calophyllaceae), NossaSenhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Transverse section. (B) Radial longitudinal section. (C) Tangential longitudinal section. (D–E) Pillar of the bell tower structure.

Cedrela sp. -Meliaceae (Figure 7)

Growth rings: distinct, delimited by regular marginal parenchyma bands and by vessels with larger tangential diameters forming semi-ring-porous patterns; vessels mostly solitary or in groups of 2 – 5; tangential diameter 100–200 µm; frequency ≤ 5 vessels/mm²; simple perforation plates; alternate, polygonal, small intervascular pits (4–7 µm); ray–vessel pits similar in size and shape. Fibers: simple to minute pits; non-septate; thin-walled. Axial parenchyma: paratracheal scanty, vasicentric, and in bands 5–10 cells wide; fusiform series with 5–8 cells. Rays: 2–3-seriate, heterogeneous, with procumbent body and 1 marginal row of square or upright cells; frequency 4–12/mm. Prismatic crystals present in marginal ray cells.

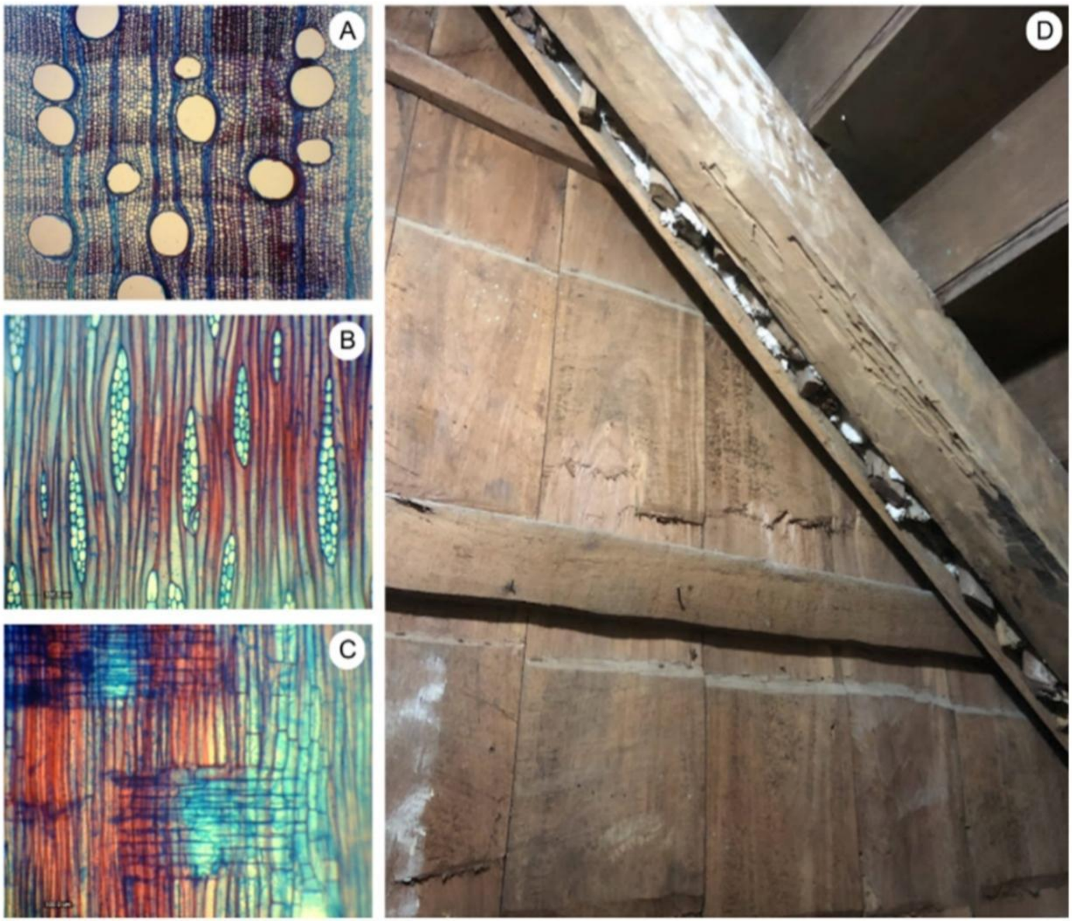

Figure 7. Constructive element and respective wood anatomy of Cedrela sp. (Meliaceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Transverse section. (B) Radial longitudinal section. (C) Tangential longitudinal section. (D) Cross beam of the wall beneath the sacristy staircase.

Licaria sp. -Lauraceae (Figure 8)

Growth ring: indistinct or absent. Vessels: diffuse-porous; in multiples of 2 – 6, rarely solitary; tangential diameter 100–200 µm; frequency 20–40 vessels/mm²; length 350–800 µm; simple perforation plates; alternate, medium intervascular pits (7–10 µm); ray–vessel pits with reduced or simple borders, rounded or angular; tyloses common. Fibers: simple to minute pits; septate; thin- to thick-walled; 900 – 1600 µm long. Axial parenchyma: paratracheal scanty; fusiform series with 3–4 cells. Rays: 1–3-seriate, heterogeneous, with procumbent body and 2–4 marginal rows of upright or square cells; 4–12 rays/mm. Oil cells associated with axial parenchyma.

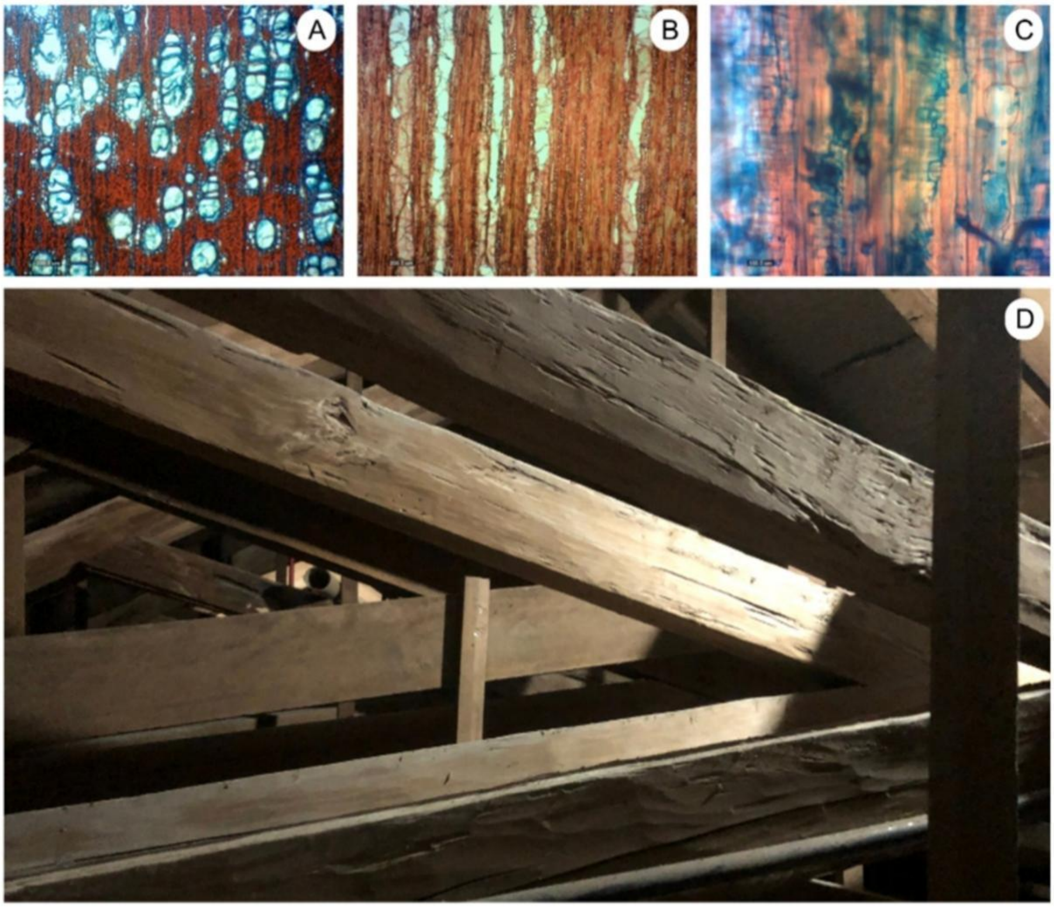

Figure 8. Constructive element and respective wood anatomy of Licaria sp. (Lauraceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Transverse section. (B) Radial longitudinal section. (C) Tangential longitudinal section. (D) Roof truss (recent piece).

Ocotea cf. cymbarum -Lauraceae (Figure 9)

Growth ring: indistinct. Vessels: diffuse-porous; solitary and in groups of 2–5; tangential diameter 100–200 µm; frequency 5–20 vessels/mm²; length 350–800 µm; simple perforation plates; alternate medium intervascular pits (7–10 µm); ray–vessel pits with reduced or simple borders, rounded or angular; tyloses common. Fibers: simple to minute pits; non-septate; thin- to thick-walled; 900–1600 µm long. Axial parenchyma: paratracheal vasicentric, aliform, aliform-lobate, and confluent; fusiform series with 3–4 cells. Rays: 1–2-seriate, heterogeneous, with procumbent body and 1 marginal row of square or upright cells; 4–12 rays/mm. Oil cells associated with ray cells.

Figure 9. Constructive element and respective wood anatomy of Ocotea cf. cymbarum (Lauraceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Floorboard. (B) Mezzanine flooring. (C) Transverse section. (D) Radial longitudinal section. (E) Tangential longitudinal section.

Ocotea porosa -Lauraceae (Figure 10)

Growth ring: distinct by fiber wall thickening. Vessels: diffuse-porous; solitary and in groups of 2 – 3; tangential diameter 100 – 200 µm; frequency 5 – 20 vessels/mm^2; length ≤ 350 µm; simple perforation plates; alternate medium intervascular pits (7 – 10 µm); ray – vessel pits apparently simple, with reduced, rounded, or angular borders; tyloses common. Fibers: simple to minute pits; septate and non-septate; thin- to thick-walled; 900–1600 µm long. Axial parenchyma: paratracheal scanty; fusiform series with 3–4 cells. Rays: 1–3-seriate and 4–10-seriate; 4–12 rays/mm. Oil cells associated with ray cells.

Figure 10. Constructive element and respective wood anatomy of Ocotea porosa (Lauraceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Transverse section. (B) Radial longitudinal section. (C) Tangential longitudinal section. (D) Bell tower railing. (E) Sacristy access frame. (F) Baluster of the museum railing. (G) Step below the sacristy staircase. (H) Roof truss (old piece). (I) Roof lining.

Ocotea sp. -Lauraceae (Figure 11)

Growth ring: distinct by fiber wall thickening. Vessels: diffuse-porous; solitary and in groups of 2 – 4; tangential diameter 100–200 µm; frequency 5–20 vessels/mm^2; length 350–800 µm; simple perforation plates; alternate medium intervascular pits (7 – 10 µm); ray – vessel pits apparently simple, with reduced, rounded, or angular borders; tyloses common. Fibers: simple to minute pits; septate; thin- to thick-walled; 900–1600 µm long. Axial parenchyma: paratracheal scanty; fusiform series with 3 – 4 cells. Rays: 1 – 3-seriate, heterogeneous; 4 – 12 rays/mm. Oil cells associated with ray cells; gum deposits present in vessels.

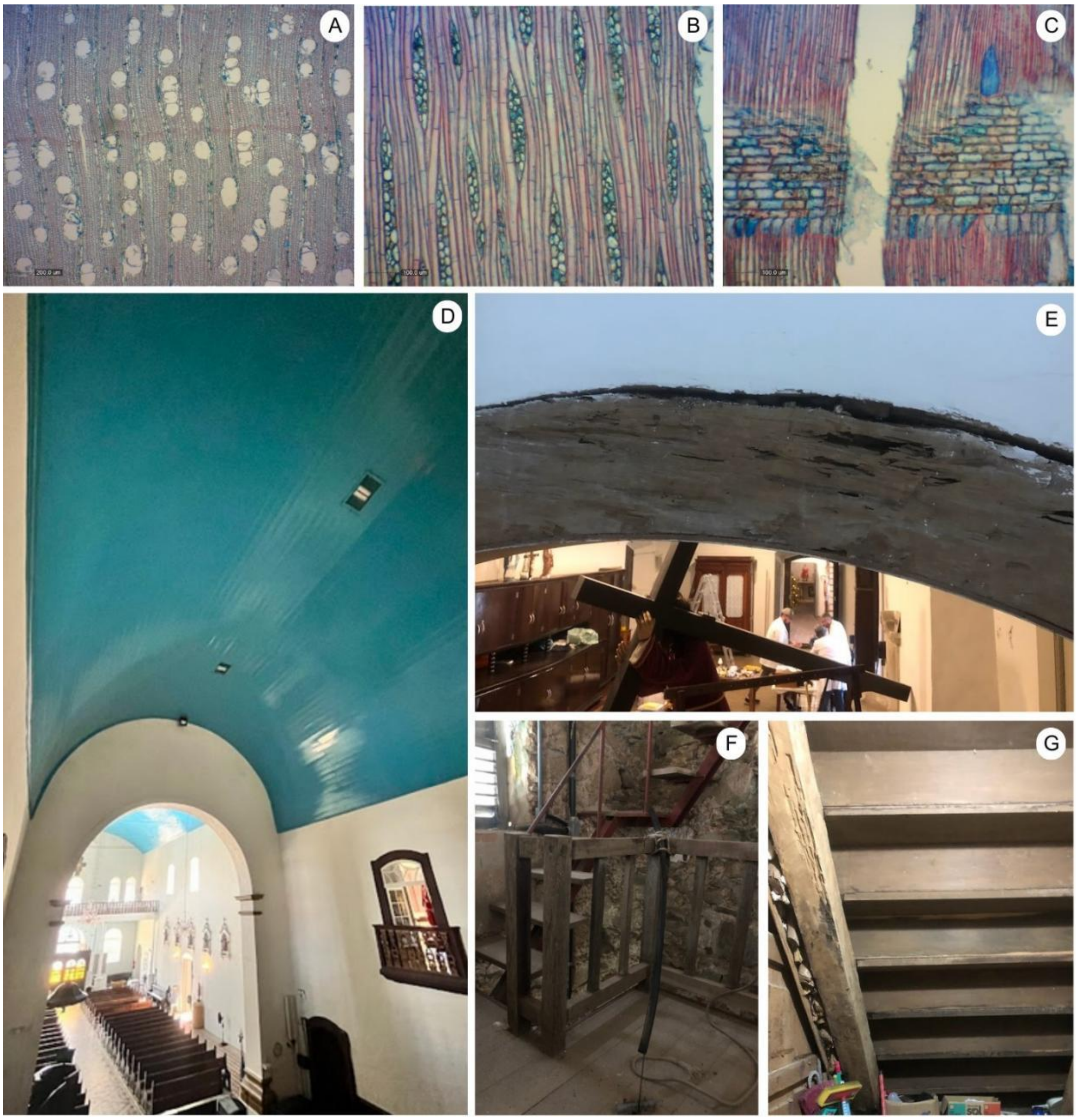

Figure 11. Constructive element and respective wood anatomy of Ocotea sp. (Lauraceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Transverse section. (B) Radial longitudinal section. (C) Tangential longitudinal section. (D) Roof lining. (E) Access frame to the sacristy. (F) Railing of the access to the bell tower. (G) Step at the bottom of the sacristy stairs.

Handroanthus sp. -Bignoniaceae (Figure 12)

Growth rings: distinct, delimited by radial thickening of fiber walls; vessels mostly solitary and in pairs; tangential diameter 50 – 100 µm; frequency 5 – 20 vessels/mm²; simple perforation plates; alternate, polygonal, large intervascular pits ≥ 10 µm; ray–vessel pits similar in size and shape.

Fibers: simple to minute pits; non-septate; thin- to thick-walled. Axial parenchyma: paratracheal unilateral; fusiform series with 3 – 4 cells. Rays: 2 – 3-seriate, stratified, heterogeneous, with procumbent body and one marginal row of square or upright cells; 4–12/mm.

Figure 12. Constructive element and respective wood anatomy of Handroanthus sp. (Bignoniaceae), Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: (A) Transverse section. (B) Radial longitudinal section. (C) Tangential longitudinal section. (D – G) Frames present in the building

Table 1. Morphological, physical, mechanical, and pathological resistance characteristics of the wood species used in the Igreja Matriz Nossa Senhora da Graça, São Francisco do Sul, Santa Catarina State, Southern Brazil. Caption: Wd -wood density (g/cm³); ShrR = radial shrinkage; ShrT = tangential shrinkage; Comp. = compression strength parallel to grain; Bend = bending strength; Shear = shear strength; Cleav. = cleavage strength; Crush Res. = crushing resistance; Impact Res. = impact resistance; Janka = hardness; DBH = estimated tree diameter at breast height.

Family	Taxon (common name)	Wd (g/cm³)	ShrR (%)	ShrT (%)	Comp. (MPa)	Bend (MPa)	Shear (MPa)	Cleav. (MPa)	Crush Res.	Impact Res.	Janka (N)	DBH (cm)	Constructive element
Apocynaceae	Aspidosperma sp. (peroba)	0.80–0.95 (high)	2.5–3.2	6.0–7.5	54–66	90–120	10–14	7–10	strong	medium–strong	25	100	Step of the bell tower staircase
Bignoniaceae	Handroanthus sp. (ipê)	≥1.00 (very high)	4	7.0–10.0	70–95	120–160	12–18	10–15	very strong	very strong	30	80	Sacristy window; bell base beam; mezzanine door; main door
Calophyllaceae	Calophyllum brasiliense (olandi)	0.54–0.62	5.4	8.4	53.25	87.67	–	10.59	strong	strong	25	150	Central pillar of the bell tower staircase
Meliaceae	Cedrela sp. (cedro)	0.40–0.55 (low)	1.8–2.4	4.0–6.0	28–40	50–70	5–7	6–8	low	low–medium	40	300	Wall crosspiece below staircase; wall/sacristy under staircase
Lauraceae	Licaria sp. (louro)	0.68–1.25	5.4	7.9	52–85	97–165	12–17	10–16	very strong	very strong	35	60	Roof truss (new piece)

Family	**Taxon (common name)**	**Wd (g/cm³)**	**ShrR (%)**	**ShrT (%)**	**Comp. (MPa)**	**Bend (MPa)**	**Shear (MPa)**	**Cleav. (MPa)**	**Crush Res.**	**Impact Res.**	**Janka (N)**	**DBH (cm)**	**Constructive element**
Lauraceae	Ocotea cf. cymbarum (louro-mamorim)	0.65 (estimated)	2.5–3.0	6.0–7.0	32–56	65–99	7–9	8	strong	medium–strong	35	50	Floorboards; mezzanine flooring
Lauraceae	Ocotea sp. (canela)	0.65 (medium)	2.7 (low)	6.3 (low)	44.12 (medium)	91.59 (medium)	9.61 (medium)	7.64 (medium)	strong	strong	28	120	Frame accessing staircase/sacristy; step and underside of sacristy staircase; handrail to bell; roof lining
Meliaceae	Cedrela sp. (cedro)	0.40–0.55 (low)	1.8–2.4	4.0–6.0	28–40	50–70	5–7	6–8	low	low–medium	40	300	Wall crosspiece below staircase; wall/sacristy under staircase
Lauraceae	Licaria sp. (louro)	0.68–1.25	5.4	7.9	52–85	97–165	12–17	10–16	very strong	very strong	35	60	Roof truss (new piece)
Lauraceae	Ocotea cf. cymbarum (louro-mamorim)	0.65 (estimated)	2.5–3.0	6.0–7.0	32–56	65–99	7–9	8	strong	medium–strong	35	50	Floorboards; mezzanine flooring

Family	Taxon (common name)	Wd (g/cm³)	ShrR (%)	ShrT (%)	Comp. (MPa)	Bend (MPa)	Shear (MPa)	Cleav. (MPa)	Crush Res.	Impact Res.	Janka (N)	DBH (cm)	Constructive element
Lauraceae	Ocotea sp. (canela)	0.65 (medium)	2.7 (low)	6.3 (low)	44.12 (medium)	91.59 (medium)	9.61 (medium)	7.64 (medium)	strong	strong	28	120	Frame accessing staircase/sacristy; step and underside of sacristy staircase; handrail to bell; roof lining

The genus Ocotea is predominant, used in approximately two-thirds of the analyzed constructive elements, reinforcing its historical and functional importance in the building. Ipê, including occurrences attributed to the genus Handroanthus, appears in high-performance elements such as doors and the bell structure, totaling around 17% of uses. The remaining genera show isolated occurrences (each around 4%), applied in specific contexts such as steps, crossbeams, and more recently replaced components (such as Licaria in the new roof truss) (Figure 13).

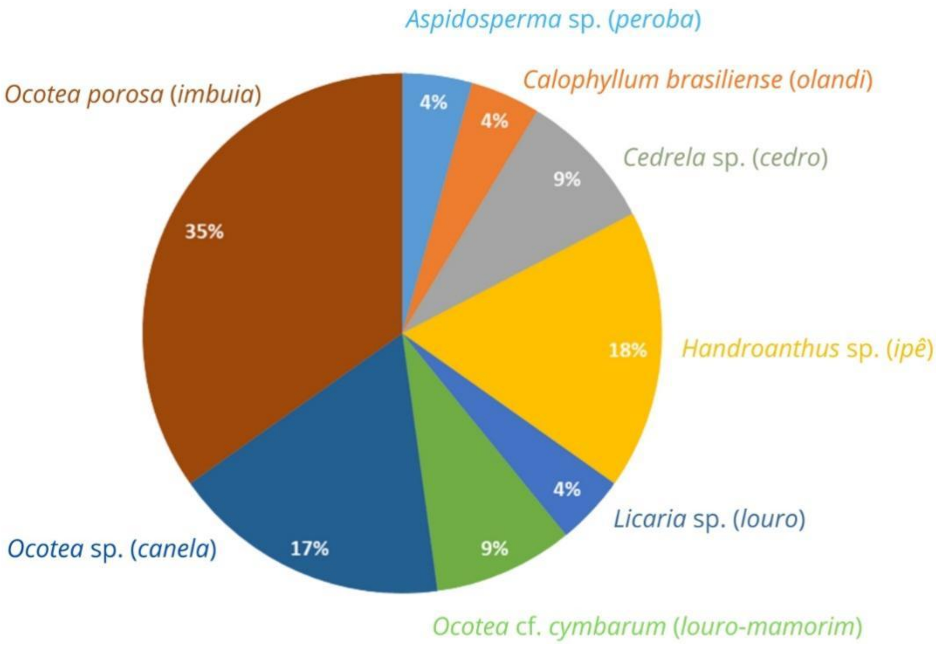

Figure 13. Distribution of the taxa identified in the traditional architecture of Nossa Senhora da Graça Church, São Francisco do Sul, Santa Catarina State, Southern Brazil

The most represented taxa among the structural and finishing elements belong to the genus Ocotea, particularly Ocotea sp. and O. cf. cymbarum, accounting for approximately 65.2% of the recorded occurrences (15 out of 23 sampled elements). This finding highlights its recurrent use as a structural element in the construction. Other species were also used in relevant structural components, such as ipê (Handroanthus sp.), identified in windows, doors, and the bell base, and peroba (Aspidosperma sp.), employed in the bell tower stair step, whose wood exhibits high density and resistance to xylophagous organisms. Ocotea sp. was found in wattle-and-daub wall components and crossbeams, whereas Cedrela sp. appears in the lower structure of the staircase -both suggesting the use of woods with good structural performance but lower natural durability compared to ipê or peroba.

The most recent pieces, such as the roof truss (replaced during restoration in the 1960s), were made with Licaria sp., a less traditional wood, indicating contemporary substitution with a species different from the original materials.

In general, elements subject to higher load and wear -such as floors, steps, the bell tower structure, and doors-were made of high-density and resistant woods. Conversely, the presence of multiple Ocotea species demonstrates a regional constructive preference or local availability at the time of the original building.

The identification of O. cf. cymbarum among the woods used in the building is noteworthy, as this is typically an Amazonian species (Lorenzi, 1992). Its occurrence in a structure located in southern Brazil raises the hypothesis that these pieces may have been reused from previous constructions, possibly dismantled ones, since the wooden structures underwent restoration in the early 2000s.

The reuse of structural elements, especially noble woods, is a recurring practice in traditional architecture and restoration processes, driven by both economic and conservation principles (Gonçalves, 2008; Brasil, 2010). Whenever possible, conservation practices seek to employ the same species used originally; when that is not feasible, species with similar physical-mechanical and anatomical properties are selected to preserve the structural behavior and aesthetic integrity of the cultural asset (ICOMOS, 2013).

The analysis of the wood species present in the building highlights both the technical knowledge involved in its construction and the dynamics of material use and reuse over time. The expressive presence of the genus Ocotea, combined with the occurrence of Handroanthus, Aspidosperma, Cedrela, and Licaria, reveals diversity and adaptability in wood selection -usually conditioned by local availability or by specific needs for replacement during restoration. The hypothesis of reused pieces from other structures -as in the case of O. cymbarum, of Amazonian origin -reinforces this perspective, indicating a common practice in historical buildings and later interventions.

This compositional complexity of wooden materials in historical buildings broadens the understanding of past construction contexts, integrating factors such as forest resource access, trade routes, technical decisions, and local cultural practices. Within this framework, the study of Nossa Senhora da Graça Church in São Francisco do Sul reveals the richness of colonial constructive traditions and their relationship with the natural resources available in the region. The building was erected with a stone structure, while wood appears in several important components -such as some wall closures (wattle-and-daub), window and door frames, ceilings, flooring, and especially the roof structure, which concentrates most of the wood used in the edifice.

Discussing wooden cultural heritage, Domínguez-Delmás et al. (2023) highlight that timber structures, particularly roof frameworks, represent valuable resources for studying wood supply, trade, construction activities, and their evolution over time. According to the authors, most studies on wood in historical buildings focus on roof structures, which are the parts where wood use is most prominent (Domínguez-Delmás et al., 2023).

Another important aspect is the relationship between the woods used in construction and their availability in local forests, a recurrent characteristic of historical buildings. A study by Charruadas et al. (2022) examined the origin and use of wood in historical buildings in Brussels, Belgium, between the 12th and 19th centuries, based on archaeological and dendrochronological data from 128 sites. The research found that oak (Quercus robur and Q. petraea, Fagaceae) was the main wood used in roof structures until the 17th century, chosen for its strength and regional abundance. This pattern demonstrates that historical constructions generally relied on native and readily available species.

Similarly, in Nossa Senhora da Graça Church, a comparable strategy may be inferred regarding wood selection. The wood employed in this building reflects both knowledge and mastery of local forest resources and traditional woodworking techniques. Studies of built heritage in southern Brazil have reported the use of dense, biodeterioration-resistant woods in structural bases and lighter woods in roof structures (Melo Júnior & Boeger, 2015; Melo Júnior et al., 2025). A parallel case is that of Nossa Senhora do Carmo Church in Diamantina, built between 1760 and 1784, whose architectural style and construction techniques resemble those of Nossa Senhora da Graça Church. The wooden structure of that church showed pathological manifestations related to weathering, such as decay due to moisture, loss of connection between elements, and material loss caused by xylophagous insects (Torres et al., 2019).

The restoration of historic buildings with wooden structures requires anatomical knowledge of the employed species, as this allows for material identification and understanding of technological properties -fundamental to explain their choice and application in construction (ICOMOS, 1999). A remarkable example is the restoration of Notre-Dame Cathedral in Paris, whose roof was destroyed by fire in April 2019. The analysis of the remaining wood, even after burning, revealed valuable information about its origin. Among more than 2,600 analyzed pieces, about one-quarter dated back to the Middle Ages, while most belonged to the 19th century, during a major restoration phase. The structural characteristics of the samples made it possible to identify forest management practices and aspects of medieval European timber trade and economy. They also provided insights into historical climate conditions, wood provenance, and carpentry techniques of the period (Quirino, 2024). The roof structure consisted of oak beams (Quercus sp., Fagaceae), a species widely distributed around Paris and abundant in natural forests. The roof and spire were supported by a complex framework known as the "forest," named for the large number of trunks used -estimated between 800 and 1,000 oaks (Quirino, 2024). Such analyses enabled the faithful reconstruction of the Notre-Dame Cathedral in accordance with its original design.

Therefore, the study of religious buildings in Brazil and elsewhere shows that wood played a central role in constructive practices, combining functionality and symbolism. Its properties -such as versatility, ease of processing, structural strength, and aesthetic value -justify its extensive use in religious architecture throughout history. In the case of Nossa Senhora da Graça Church in São Francisco do Sul, wood also represents a cultural heritage element, preserving collective memory and strengthening the link between the city's historical past and its present identity.

CONCLUSION

Nossa Senhora da Graça Church represents a significant 17th-century architectural work, whose construction involved the use of wood in its structure, reflecting both empirical knowledge of timber and traditional building practices of the time. Wood, an essential material in the construction, is present in several parts of the church - from the roof structure to staircases and frames -demonstrating its importance for both preservation and functionality.

The results indicate that the choice of wood species was directly related to regional availability and their resistance and durability characteristics, a common practice in historical buildings. Woods from species of the genus Ocotea (Lauraceae) were predominant, presenting wide distribution and diversity in the forests of southern Brazil.

This research contributes to the valorization of built heritage, providing insights for future conservation and restoration interventions. However, challenges remain, such as the scarcity of detailed historical documentation and limited access to certain structural components, which restrict deeper analyses. Future studies may expand this investigation through dendrochronological and comparative methods, enabling a more precise understanding of the origin of the woods used and their relationship with timber trade and forest management during the colonial period.

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ETHICAL DECLARATION

Conflict of interest: No declaration required. **Financing:** This work was supported by the Research Support Fund of the University of the Region of Joinville (ID405), Foundation for Research and Innovation Support of Santa Catarina (2023TR000901), and National Council for Scientific and Technological Development (CNPq 308777/2025-5). **Peer review:** Double anonymous peer review.