Department of Architecture and design
Master's thesis in architecture for heritage
A.A. 2025/2026

The Limitations and Reinterpretation of Authenticity in Wooden Structural Systems:

A Comparative Study between Italy and China

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Abstract

Wooden historic buildings have long occupied a theoretical blind spot within the international heritage conservation framework. Modern conservation principles—particularly the concept of “authenticity”—emerged primarily within Europe's stone-dominated cultural context, implicitly premised upon assumptions of “material durability” and “formal stability”. Wooden structures, however, exhibit cyclical renewal, high replaceability, and strong craft dependency, their modes of continuity fundamentally diverging from stone-built architecture. Applying the concept of “authenticity” directly to timber-framed systems inevitably generates theoretical contradictions.

This study examines the timber-framing traditions of Italy and China, exploring how different cultures reinterpret authenticity within the timber-framing context through three perspectives: conceptual responses, structural logic, and joint construction and restoration practices. Part One reviews the formation and institutionalization of authenticity, alongside responses from China and Italy. Part Two examines fundamental structural differences: China's modular, reversible mortise-and-tenon joints center authenticity on craftsmanship and spatial order, while Italy's truss systems rely on holistic mechanical interactions. These two structural systems give rise to two equally valid yet logically distinct conceptions of authenticity: China's ‘structural logical continuity authenticity’ and Italy's ‘structural system integrity authenticity’.

Part Three demonstrates the choice logic in actual restoration practices through four typical case studies. Italy adheres to minimal intervention and reversible reinforcement, preserving structural authenticity by restoring the truss's mechanical behavior. China, building upon its tradition of restoring old structures to their original state, has gradually shifted towards scientific restoration grounded in historical surveying, craft systems, and structural order, cautiously exploring new approaches. The cases clearly demonstrate: the authenticity of timber architecture cannot be judged solely by material preservation but must simultaneously consider its structural mechanisms, historical construction, and cultural context.

The study ultimately concludes that authenticity is not a fixed universal standard, but a dynamic principle continually redefined within distinct structural systems, cultural logics, and craft traditions. Re-examining authenticity through the lens of timber structures facilitates the advancement of an internationally oriented heritage conservation discourse that is more structurally sensitive and culturally inclusive, offering new theoretical pathways for the future preservation of timber heritage.

KEYWORDS: Timber architecture; authenticity; restoration theory; structural logic; mortise-and-tenon; truss systems; structural authenticity; cultural continuity

Statement on the Use of Language-Enhancement Tools

This thesis was written by the author. During the writing process, the author used ChatGPT and DeepL for language polishing, grammar refinement, and partial translation of non-original text. All academic ideas, structural design, analytical content, and research conclusions are entirely the author’s own. The use of these tools did not influence the conceptual development or scholarly arguments of the thesis.

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Chapter 1 Introduction

1.1 Research Background

Historical timber structures constitute a vital component of humanity's architectural heritage, embodying multiple dimensions of structural ingenuity, spatial conception and cultural significance. They represent not merely architectural artistry, but also serve as tangible repositories of historical memory, religious observances and social organization. Wood, with its natural, renewable and workable properties, has long served as the primary building material across numerous civilizations. However, precisely due to its organic nature, timber structures are highly susceptible to damage from insect infestation, decay, fire and climate change, making them among the most complex and sensitive subjects in heritage restoration and conservation.

However, within the broader international context of conservation, the restoration theory centered on “authenticity” has its roots firmly planted in Europe's cultural milieu, where stone masonry predominates. When applied to timber structures, it reveals limitations due to material differences. This observation is not without basis, as Jukka Jokilehto observes:

“Western conservation thought was born within a culture of masonry architecture, where permanence of materials was equated with permanence of values.” [1]

Western architectural heritage is characterized by masonry materials and arched structures. These stone and brick constructions, with their form and structure, demonstrate far greater resilience against the ravages of fire, water, and biological

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[1] Jukka Jokilehto, *A History of Architectural Conservation* (Oxford: Butterworth-Heinemann, 1999), 75.

decay than timber buildings, possessing relative durability. This is thus regarded as the cultural foundation underpinning Western architects' and conservators' reverence for the principle of authenticity in heritage preservation.[2]

However, Chinese scholar Chen Zhihua concurrently affirms the universality of "authenticity", stating:

"Within the prevailing Western values, principles, and methodologies for heritage building conservation, one cannot discern that they originated solely from the maintenance of stone structures. They articulate general, fundamental theories unrelated to specific building materials, construction techniques, and so forth."[3]

Western architectural heritage may superficially appear defined by masonry, yet stone and brick constitute merely the building's shell. Internally, these structures predominantly feature timber-framed floors, roof trusses, and roofing. Western architecture often represents composite constructions of masonry and timber. The principles and concepts advocated by Western heritage conservation scholars for such buildings are equally applicable to the preservation and restoration of East Asian timber structures.

Consequently, this paper does not deny the status and value of authenticity but rather focuses on the contradictions and limitations that arise when authenticity is applied to timber structures. Whether in Italy or China, timber components invariably prove less durable than masonry.[4] To maintain the building's overall stability, restorers

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[2] Sun Hua, "On Architectural Heritage Conservation: The Timber-Structured Construction Protection and Restoration," *Palace Museum Journal* 270, no. 10 (2024): 12-15. (in Chinese)

[3] Chen Zhihua, "Wenwu jianzhu baohu de jiazhi guan wenti" [On Value Judgments in the Conservation of Historic Architecture], *World Architecture*, no. 7 (2003): 81. (in Chinese)

[4] Strictly speaking, wooden artefacts can endure for centuries if properly preserved and maintained. Wooden structures in arid desert regions may survive for millennia; for instance, the 3,500-year-old wooden sacrificial hall, railings, markers, and coffins from the Xiaohe burial site in Lop Nur, Xinjiang, remain intact to this day. Wooden structures in waterlogged environments can also endure for millennia. For instance, the multiple coffins and lacquered wooden burial objects from the 2,500-year-old Zeng Hou Yi tomb in Suizhou, Hubei, remain remarkably well-preserved. Within the heritage sector, the adage

are often compelled to replace old elements with new timber, yet such interventions push against the boundaries of the authenticity principle.[5]

In China, data from the third national cultural relics census released by the Shanxi Provincial Cultural Relics Bureau in 2010 revealed that the province had registered 55,575 immovable cultural relics, including 28,640 ancient buildings. This represents approximately 10.85% of China's total ancient architectural heritage, encompassing world-class sites such as Foguang Temple, the Yingxian Wooden Pagoda, and the Main Hall of Nanchan Temple.[6] However, this high concentration also signifies significant vulnerability. Under the combined pressures of natural ageing, inadequate maintenance, and urban renewal initiatives, numerous lower-tier immovable cultural relics—such as rural religious and vernacular timber structure remain excluded from statutory protection frameworks. These diverse and scattered sites often endure prolonged neglect, collapse, or reconstruction.[7]

In Italy, despite a predominance of masonry construction, timber-framed roofs play an equally irreplaceable role in historic buildings. Yet due to their perishable nature, concealed structural elements, and challenging assessment requirements, timber structures are frequently overlooked or misjudged during restoration, leading to issues such as material substitution or inappropriate structural reinforcement.[8] Furthermore,

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'paper lasts a thousand years, silk eight hundred' refers to the longevity of long-fibre paper made from wood and grass-based plants, which can endure for over a millennium. However, the structural integrity of timber components in buildings is compromised by repeated historical upheavals and the absence of maintenance.

[5] ICOMOS. *The Venice Charter: International Charter for the Conservation and Restoration of Monuments and Sites* [EB/OL]. 1964. https://www.icomos.org/charters/venice_e.pdf.

[6] Huizhi Li, Distribution and Regional Characteristics of Wooden-Frame Buildings Before Yuan Dynasty in Shanxi Province, *Chinese Ancient Architecture Heritage Research* 6, no. 1 (2021): 2. (in Chinese)

[7] Shanxi Provincial Government. "Guanyu jiaqiang Shanxi fei wenbao lishi jianzhu baohu de tongzhi" [Notice on Strengthening the Protection of Non-Registered Historic Buildings in Shanxi]. Shanxi Public Resources Trading Center, last modified May 19, 2025. https://www.ggzy.gov.cn/html/b/140000/0201/202505/19/001467cfe9812afe48d98e630b89cc891a5a.shtml(in Chinese).

[8] Clara Bertolini Cestari and Tanja Marzi, "Conservation of Historic Timber Roof Structures of Italian Architectural Heritage: Diagnosis, Assessment, and Intervention," *International Journal of Architectural Heritage* 12, no. 4 (2018): 632.

frequent seismic activity exacerbates damage to timber components. For instance, following the 2009 L'Aquila earthquake, numerous medieval roof systems collapsed due to joint failure, exposing dual deficiencies: inadequate seismic resilience of timber structures and lagging restoration techniques.

1.2 Research Objectives and Questions

Wooden structures have been integral to China's architectural development throughout its history. In contrast, Western nations including Italy have employed stone masonry to express permanence, yet timber construction has never been marginalized, possessing its own distinctive history of wooden building techniques. While cultural, structural, and constructional logics differ between the two nations, the issue of timber restoration—when considered within the context of authenticity—reveals a shared dilemma: how to achieve the authenticity of wooden structures.

Consequently, this study transcends mere comparisons of restoration philosophies or structural variations between Chinese and Italian timber frameworks. Organized into three sections, it constructs a three-dimensional analytical framework of 'Structure-Philosophy-Technique'. Grounded in theoretical foundations, it identifies contradictions in timber restoration, addresses structural limitations causing these tensions, and suggests that 'authenticity' is not a fixed concept but a principle guiding diverse developmental approaches. Finally, restoration case studies provide a more detailed illustration of the restoration choices made in China and Italy.

The primary research questions are:

1. Within the context of timber structure conservation, what differences exist in the Chinese and Italian understandings of authenticity? What are the underlying philosophical principles?

2. How do the characteristics and fundamental structural differences of historical timber structures in both countries influence subsequent restoration choices?

3. How do these conceptual differences manifest in practical conservation interventions? For instance, how are they reflected in material treatment, structural interventions, or decisions regarding reconstruction?

4. Is it possible to propose an integrated conservation strategy that balances cultural continuity with material authenticity, thereby better addressing the diverse conservation needs of timber heritage worldwide?

Part I: The Formation, Limitations and Development of Authenticity Concept

In A History of Architectural Conservation, Jukka Jokilehto observes:

"Cultural heritage may be defined as the entirety of material symbols—be they artistic or symbolic, bequeathed by history to each culture and indeed to all humankind. As a confirming and enriching component of cultural identity, and as a heritage belonging to all humanity, cultural heritage endows each specific location with its recognizable character, constituting a repository of human experience. Thus, the conservation and presentation of cultural heritage form the cornerstone of any cultural policy." [9]

As Jukka Jokilehto observes, the conservation of cultural heritage concerns not merely 'how to restore,' but equally 'why to restore'—a matter intrinsically linked to each nation's culture, spirit, and policy. Only by deeply understanding the formation of historical building conservation concepts, particularly those originating in Italy, and by examining the definition and value of authenticity, can one truly grasp the cultural logic underlying the act of "restoration". In fact, architectural restoration has never been merely a matter of engineering choices; it is fundamentally a judgement about what constitutes authenticity and what holds value.

"Authenticity" is widely regarded as the most central ethical standard. From the Venice Charter (1964) to the Nara Document (1994), it consistently served as a benchmark for evaluating heritage value and the legitimacy of restoration. However, this theory emerged from Europe's tradition of stone-based architecture, its philosophical underpinnings implicitly assuming 'material continuity' and 'form stability' – the 'truth' of a building lies in preserving its original materials and form.

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[9] Jukka Jokilehto, *A History of Architectural Conservation*, 1.

In practice, however, when applied to predominantly timber-framed systems characterized by replaceability and cyclical maintenance, this concept reveals its limitations. The authenticity of timber architecture does not depend on retaining original materials, but rather on preserving structural logic and craftsmanship continuity. In other words, authenticity carries distinct meanings across different materials and cultural contexts.

This section therefore traces the conceptual formation and institutionalization of authenticity from a theoretical perspective. It examines its philosophical underpinnings and theoretical boundaries within stone-built traditions, revealing the contradictions and challenges that arise when this concept confronts timber-based architectural systems. This theoretical retrospective will clarify the limitations and reinterpretations of "authenticity" when applied to timber-based architectural systems, laying the intellectual groundwork for subsequent comparative and structural analyses between Chinese and Italian traditions.

Chapter 2 The Emergence of "Authenticity" Represented by Italy

Europe stands not only as the birthplace of global heritage conservation theory and practice but also as the core founder of modern conservation principles.

However, this system did not emerge overnight; it evolved through centuries of intellectual and practical accumulation. From the classical era's reverence for monumental architecture, through medieval religious and political patronage of preservation, to the Renaissance's misguided exploitation of antiquities as utilitarian resources, European society's approach to historical sites evolved through twists and turns. This journey shifted from functional and symbolic reconstruction and utilization towards the preservation and respect of authenticity.

Italy has consistently played a pivotal role in this intellectual evolution. From Renaissance studies of classical forms, through Camillo Boito's 19th-century principle of 'distinguishing the old from the new,' to Cesare Brandi's 20th-century 'Theory of Restoration' centered on authenticity, Italy progressively established an ethically and philosophically grounded restoration framework.[10] The 1964 Venice Charter elevated these principles to the international stage, establishing them as the theoretical benchmark for global heritage conservation.[11]

This chapter therefore traces the historical evolution of authenticity thinking through an Italian lens—from early 'monumental consciousness' to the establishment of 'historical value' and 'authenticity' concepts—demonstrating how authenticity attained its central position within European conservation philosophy.

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[10] Ibid., 200-237.

[11] Werner von Trützschler, "The Evolution of 'Cultural Heritage' in International Law," in *Monuments and Sites in Their Setting: Conserving Cultural Heritage in Changing Townscapes and Landscapes*, (ICOMOS, 2005), 1–15.

2.1 Authenticity precedes: Early European notions of heritage

In ancient societies, the "continuity" of architecture was grounded more in memory and symbolism than in the preservation of historical authenticity. Mediterranean civilizations, such as Greece, Rome, and even Egypt and Persia, demonstrated a consciousness of historical space and a desire for cultural continuity through architectural interventions, functional transformations, and symbolic reconstruction. [12] These actions stemmed from multiple motivations—religious devotion, legitimizing rule, commemorative significance, and practical utility—rather than prioritizing "authenticity" or "preserving historical appearance".

The etymology of "monument" further illuminates the cultural logic underpinning ancient conservation practices. 'The Greek word for 'monument' (μνημεῖον, deriving from memory, mneme) was related to memory, a 'memorial', while the corresponding Latin word (monumentum, deriving from moneo) encompassed political and moralistic issues, intended to admonish and remind the spectator of the power of the governors.'[13] Greek monuments emphasized remembrance, whereas Roman ones primarily served to manifest state authority. Consequently, ancient architectural interventions leaned more towards 're-imaging' than 'preserving original appearance,' driven culturally by power and memory rather than authenticity.

With the disintegration of the Roman Empire, Europe entered the Middle Ages. Architectural conservation principles were now governed by religious faith and functional continuity. Christian societies prioritized the sacredness of buildings over their historical significance; many classical ruins were preserved not for their antiquity but for their potential reuse in religious ceremonies. The reuse of building materials (spolia) became commonplace—columns and stone elements from ancient Roman

[12] Jokilehto, *A History of Architectural Conservation*, 1-2.
[13] Ibid.,4-5.

structures were frequently incorporated into churches or monasteries, symbolizing the new faith's inheritance and transcendence of the old civilization.[14] This continuity stemmed not from historical consciousness but from the symbolic reshaping of religious legitimacy.

Although the Renaissance rediscovered the artistic and proportional systems of classical architecture,[15] attitudes towards the ancient heritage during this period were not particularly respectful or consciously focused on ‘preserving antiquities.’ Instead, they were often characterized by indifference or unconsciousness, that is, the ancient world was not perceived as a ‘past’ requiring protection. For instance, Alberti, in the Tempio Malatestiano (Malatesta Temple), directly transformed ancient ruins into new structures; Peruzzi even built new structures directly atop the ancient Theatre of Marcellus.

Despite the absence of formal restoration theory in antiquity, the works of Vitruvius and others revealed nascent awareness of historical, environmental, and cultural continuity. Though the term ‘restoration’ did not exist in classical times, it is noteworthy that the architect Vitruvius, in his Ten Books on Architecture, articulated design principles closely linked to preservation. He emphasized that architecture should be site-specific, considering natural factors such as climate, orientation, and humidity. Simultaneously, he advocated that architects must possess an understanding of history and culture to correctly employ components of symbolic significance.[16] This perspective not only reflects an early recognition of the “spirit of place” but also reveals the close connection between the cultural, technical, and structural logic of architecture.

In other words, architectural conservation was never a purely technical endeavour from its inception, but rather a dynamic process integrating material, environmental,

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[14] Ibid., 14–15.
[15] Ibid., 15–16.
[16] Ibid., 3.

and cultural considerations. Although Vitruvius did not explicitly formulate the concept of ‘restoration,’ his sensitivity to context and history demonstrates an early understanding of architectural and cultural continuity. This provides valuable insights for this paper's exploration of the limitations and re-evaluation of subsequent restoration philosophies within the context of timber structures.

2.2 The Emergence of the Concept of Authenticity

The Enlightenment and Age of Reason spanning the 17th and 18th centuries witnessed a fundamental shift in European society's understanding of historic architecture. Buildings were no longer viewed merely as religious symbols or classical paradigms, but rather as material testaments to the evolution of human civilization. Advances in historiography, archaeology and the natural sciences enabled architecture to be systematically studied for the first time. Architectural remains were accorded with the status of ‘verifiable historical evidence’, laying the methodological foundations for the subsequent concept of ‘scientific restoration’.

Archaeological discoveries of the 18th century, particularly the excavations at Pompeii and Herculaneum, intensified awareness of ‘authenticity’ and ‘original appearance.’ Scholars first distinguished between “restoration” and ‘replication,’ advocating the preservation of historical traces for research and education. This shift heralded authenticity's transition from ‘formal ideals’ to ‘historical consciousness’: a structure's value no longer hinged on visual perfection but on its ‘temporal legibility’.

By the 19th century, industrial expansion and urban destruction spurred the modern conservation movement. The Romantic revival imbued architectural heritage with emotional and cultural significance. Eugène Viollet-le-Duc proposed the concept of ‘stylistic restoration,’ arguing that repairs should ‘restore the building to its ideal state’—even if that state had never historically existed. This pursuit of ‘idealized authenticity' prioritized formal purity, often erasing historical layers and substituting 'aesthetic unity' for 'historical veracity.'

In contrast stood John Ruskin's 'anti-restoration' philosophy. In The Seven Lamps of Architecture (1849)[17] and The Stones of Venice (1851), he declared: 'To restore is to lie.' He contended that a building's value lies in its 'traces of time' and 'imprints of human labour,' asserting that any restoration negates temporal authenticity. Ruskin thus established 'temporal authenticity' as the ethical standard for conservation—advocating respect for a structure's natural ageing process to faithfully reveal its historical layers.

Camillo Boito attempted to reconcile these positions in his 1883 Memoir on Restoration. He proposed the principles of 'recognizability' and 'minimal intervention,' requiring that restored and original elements remain distinguishable yet harmonious. Boito's thinking facilitated the transition of authenticity from an "emotional ideal" to a "methodological principle", laying the ethical groundwork for the 20th-century Venice Charter.

In the early 20th century, Alois Riegl further systematized the concept of authenticity in The Modern Cult of Monuments: Its Character and Its Origin (1903).[18] He proposed a plural value framework—distinguishing, among others, commemorative values (e.g., age value and historical value) and present-day values (e.g., use value and art value)—showing that conservation choices are shaped by the prioritization of different values rather than a single standard. Concurrently, Gustavo Giovannoni introduced the concepts of 'scientific restoration' and 'holistic urban conservation,' grounding preservation in rational research and minimal intervention. This rendered authenticity an operational academic standard rather than an abstract ideal.

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[17] John Ruskin, *The Seven Lamps of Architecture*, vol. 8 of *The Works of John Ruskin*, ed. E. T. Cook and Alexander Wedderburn (London: George Allen, 1903), 262.

[18] Carolyn Ahmer, "Riegl's 'Modern Cult of Monuments' as a Theory Underpinning Practical Conservation and Restoration Work," *Journal of Architectural Conservation* 26, no. 2 (2020): 150–165, https://doi.org/10.1080/13556207.2020.1738727

Collectively, restoration theories from the nineteenth to early twentieth centuries completed a philosophical shift in the concept of authenticity—from formal reproduction to historical continuity, and from aesthetic ideals to ethical judgement. This process established authenticity as the core intellectual foundation of international restoration theory, while also revealing its 'stone culture hypothesis,' premised on 'material continuity' and 'structural stability.' This laid the groundwork for subsequent discussions on the theoretical limitations within timber-framed structures.

2.3 The Advancement and Institutionalization of Authenticity

From the latter half of the 20th century onwards, the preservation of architectural heritage gradually shifted from technical operations at the national level towards the establishment of global institutional frameworks. Following the Second World War, confronted with extensive historical destruction, the Italian theorist Cesare Brandi proposed in his Theory of Restoration (1963) that 'restoration constitutes a renewed recognition of the dual ontological nature of the work of art – both aesthetic and historical.'[19] He conceptualized authenticity as a balance between artistic unity and historical veracity, emphasizing that restoration must respect historical stratification while restoring the overall aesthetic experience. This philosophy became the theoretical foundation for the 1964 Venice Charter.[20]

The promulgation of the Venice Charter in 1964 marked the codification of modern architectural conservation principles. Building upon the 1931 Athens Charter, the Venice Charter further established restoration principles centered on 'respect for original materials' and 'minimal intervention,' opposing speculative reconstruction. In the Charter's preamble, Paul Philippot wrote:

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[19] Ibid., 46.

[20] ICOMOS. *The Venice Charter: International Charter for the Conservation and Restoration of Monuments and Sites* [EB/OL]. 1964. https://www.icomos.org/charters/venice_e.pdf.

"Imbued with a message from the past, the historic monuments of generations of people remain to the present day as living witnesses to their age-old traditions. People are becoming more conscious of the unity of human values and regard ancient monuments as a common heritage. The common responsibility to safeguard them for future generations is recognized. It is our duty to hand them on in the full richness of their authenticity." [21]

Furthermore, Article 15 of the Charter, which addresses archaeological sites, states:

"All reconstruction work should, however, be ruled out a priori. Only anastylosis the reassembling of existing but dismembered parts, can be permitted."

This reflects the fundamental principle of the Venice Charter: the conservation of architectural heritage must adhere to the principle of authenticity, preserving the material substance's historical value.[22] This charter respects material purity and rejects any speculative reconstruction. Although the term 'authenticity' is not strictly defined in the Charter's text, its ethical spirit has become a crucial theoretical foundation for all subsequent international conservation documents.

The signing of the 1972 World Heritage Convention extended the concept of authenticity from European conservation thought into a global context. The Operational Guidelines for the Implementation of the World Heritage Convention, first issued by UNESCO in 1977, explicitly stipulated that nominated heritage sites should demonstrate authenticity in four aspects: 'design, materials, craftsmanship and environment'. This institutionalized formulation established authenticity as a key criterion for assessing a heritage site's Outstanding Universal Value, marking the formal transition of authenticity from a philosophical concept to an international technical

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[21] Ibid.

[22] UNESCO World Heritage Centre, ICOMOS, ICCROM, and National Cultural Heritage Administration, *Selected International Documents on Cultural Heritage Conservation* (Beijing: Cultural Relics Press, 2007), 28–29. (in Chinese)

standard.

Chapter 3 The Limitations and Development of "Authenticity" in Timber Construction Systems

Since the mid-twentieth century, "authenticity" has become the most fundamental ethical standard in architectural heritage conservation. However, during its global dissemination and institutionalization, this concept has gradually revealed tendencies towards paradigmatic rigidity.

Within the logic of stone structures, the principle of authenticity remains valid. The durability, stability, and visible traces of stone naturally establish "preserving the original material" as the physical foundation of historical authenticity, upholding the principle of recognizability. Yet when this ethic is applied to predominantly timber-framed building systems, its internal logic begins to falter. Timber structures thrive through renewal, replacement, and periodic maintenance—their continuity depends on change, not stasis.

Consequently, since the late 20th century, scholars worldwide have reinterpreted and expanded the concept of 'authenticity' within diverse cultural and technical contexts. The most influential turning point was the 1994 Nara Document on Authenticity, jointly published by UNESCO and Japan's Agency for Cultural Affairs. This document explicitly stated for the first time that authenticity should not be confined to material form but understood diversely according to cultural contexts, traditional craftsmanship, and building materials. This perspective opened new theoretical space for non-stone building systems—particularly timber-framed cultures—and provided an opportunity for nations with rich timber construction traditions, such as Italy and China, to re-examine the concept of authenticity.

Consequently, this chapter will focus on the limitations and developments of authenticity within the context of timber construction, exploring how Chinese and Italian scholars have undertaken localized translations and reinterpretations of authenticity theory based on their respective timber-framed building systems.

3.1 Italy's Reinterpretation of Authenticity

Brandi grounded authenticity in the 'dual unity of aesthetics and history' within artistic works, positioning it as central to ethics and perception. However, this theory, taking artworks as its prototype and emphasizing visual and formal integrity, accorded relatively limited attention to architecture as a material-technical system. Entering the 1970s, Italian academia began reinterpreting this 'aesthetic bias,' progressively expanding the meaning of authenticity beyond aesthetic judgement to encompass scientific cognition and structural logic.

(1) Carbonara: From Aesthetic Authenticity to 'Critical Restoration' In a later synthetic work, *Avvicinamento al restauro (1997)*, Giovanni Carbonara proposed the theory of "critical restoration" (restauro critico). He contends that restoration constitutes a rational act grounded in the 'material and historical understanding' of the building, rather than a mere aesthetic judgement:

"Il restauro è un atto critico fondato sulla conoscenza materiale e storica dell'opera." (Restoration is a critical act founded upon the material and historical knowledge of the work.)

For Carbonara, authenticity is not blind reverence for the original appearance, but a practice maintaining equilibrium between scientific cognition and ethical judgement. Restorers must comprehend a building's structural logic and material properties, ensuring interventions both honor historical traces and comply with technical principles. This philosophy signaled authenticity's evolution from a static preservation ideal to a dynamic cognitive process, laying theoretical groundwork for subsequent discussions on structural authenticity.

(2) Marconi: In Restoration and Architecture (Il restauro e l'architettura, 1988). He argued that authenticity should not be understood as a fixed ethical category, but rather as a 'dynamic process between cognition and representation.' 'L'autenticità appartiene al processo di comprensione e di rappresentazione.'

Marconi contends that restoration is not mere 'preservation of the status quo' but rather a 'truthful reconstruction' (ricostruzione veritiera), aiming to achieve cultural continuity through the rebirth of architecture. This understanding transforms authenticity from 'static preservation' into 'truth in continuity,' thereby offering a new theoretical perspective for replaceable, maintainable buildings, exemplified by timber structures.

(3) Tampone: From Material Authenticity to Structural Authenticity By the 1980s, discussions on authenticity increasingly shifted towards the technical and structural dimensions of architecture. Gennaro Tampone, a key member of ICOMOS's Timber Structures Committee, asserted in his work La carpenteria lignea storica: conoscenza, conservazione, consolidamento (2007): 'Authenticity does not lie in preserving every single element, but in respecting the original structural logic and connection systems.'

Tampone elevates authenticity from a 'material ethic' to a 'structural ethic.' He contends that replacing certain components in timber restoration does not compromise authenticity, provided the mechanical system and craft logic are preserved. This perspective challenges the assumption of 'material continuity' rooted in stone masonry, thereby establishing the theoretical foundation for the concept of 'structural authenticity.'

In summary, the core evolution of Italian restoration theory lies in the redefinition of authenticity no longer understood solely as an aesthetic ethic for artworks or a technical imperative for material preservation, it is now reinterpreted as a balancing process between a building's "structural logic" and its "cultural continuity".

This shift not only transcends the theoretical constraints rooted in masonry architecture but also furnishes a fresh theoretical framework for the restoration of timber structures, maintaining an 'authentic equilibrium' between material renewal and structural continuity. This provides a foundational point of dialogue for discussions on Chinese timber restoration principles, while simultaneously revealing the openness and vitality of 'authenticity' within contemporary contexts.

3.2 China's Localization of 'Authenticity'

Compared to Italy's earlier development of legal and institutional frameworks within Europe, China's formal heritage conservation emerged later under Western influence, yet the 'spirit of preservation' has permeated its entire developmental history. Whereas Western thought posits that ideas can withstand the passage of time through solid stone structures, demonstrating eternity, Chinese philosophy maintains that eternal truth resides in humanity rather than stone.[23] Confronted with the introduction of authenticity, China's approach to timber structure restoration bears distinct national characteristics, deeply rooted in its unique cultural and political context. As Zhu Guangya observed:

"In China, the movement for the conservation of Chinese cultural heritage is a holistic movement. This movement seeks the protection of all aspects of Chinese cultural heritage, because such heritage cannot exist nor be understood except in relation to the interdependent parts comprising it. China's architectural heritage, one

[23] Maria Grazia Ercolino, "Patrimonio, autenticità e tradizione nella cultura cinese del XXI secolo," in *RICerca/REStauro. Sezione 1C: Questioni teoriche – storia e geografia del restauro*, edited by Donatella Fiorani (Rome: Edizioni Quasar di S. Tognon, 2013): 350. (in Italian)

facet of the nation's cultural legacy, relies upon comprehension of its various interdependent factors."[24]

China's complex geography and political landscape, coupled with profound historical transformations in modern times, have shaped its enduring yet distinctive attitude towards historic buildings—viewing them merely as one component of its cultural heritage, and not necessarily the most significant one.

The concept of authenticity in Chinese architecture emerged from the combined influence of the material properties of timber construction systems and ancient cultural philosophy. The renewability of timber, coupled with the ritualistic symbolism bestowed upon wooden structures by traditional culture, jointly determined an authenticity distinct from that of Italy.

3.2.1 The ancient restoration culture where spirit outweighed substance

Throughout China's millennia-long history, the formation and evolution of heritage conservation philosophy has been profoundly shaped by traditional thought, characterized by the core tenets of 'prioritizing the Way over artefacts' and 'perpetuating the spirit through form'. From the pre-Qin to pre-Tang era of 'veneration of antiquity for its philosophical essence', through to the Tang dynasty and modern period marked by 'symbolic and spiritual transmission', both phases collectively convey that within traditional Chinese cultural thought, unlike the Western emphasis on material permanence, China places greater value on spiritual continuity. This notion of 'spirit outweighing substance' laid the cultural foundation for Chinese authenticity.

This philosophy traces back to the Chinese philosopher Laozi, who first proposed

[24] Guangya Zhu, "China's Architectural Heritage Conservation Movement," *Frontiers of Architectural Research* 1, no. 1 (2012): 11.

'Dao'.[25] Subsequently, the "Xici" commentary of the 'Book of Changes' began exploring the relationship between 'The Way' and artefacts.[26] This concept of 'prioritising the Way over artefacts' became deeply embedded within the structural fabric of traditional Chinese culture and the behavioural habits of its people. Preservation practices in ancient society typically focused on the 'institutional principles' embodied by artefacts rather than the authenticity of their physical components.

Consequently, the value of antiquities during this period lay not in their material integrity but in the institutional frameworks, ethical systems, and cultural concepts they represented. Preservation efforts under this paradigm prioritised transmitting the institutional information and cultural significance behind objects over maintaining their original physical appearance.[27] This influenced the emphasis on reconstructing and recreating the form and function of buildings to achieve spiritual continuity in cultural heritage preservation from the Tang Dynasty to the late Qing Dynasty (618–1912 AD), establishing a tradition of 'rebuilding' damaged structures.[28]

Although the concept of authenticity had not yet been formally proposed in the West, let alone introduced to China, this period's approach to 'rebuilding' timber structures implicitly reflected an attitude towards authenticity.

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[25] The concept of *Dao* (道), as proposed by Laozi in the *Dao De Jing*, refers to the primordial origin of all things, preceding even Heaven and Earth. It is an abstract, eternal, and immutable metaphysical principle that governs all existence. Nothing precedes the *Dao*, and it remains unaffected by the transient phenomena of the material world.

[26] As recorded in the *Zhou Yi* (*Book of Changes*, *Xici I*): "形而上者谓之道，形而下者谓之器" ("What is above form is called *Dao*; what is below form is called *Qi* [vessel].") This distinction expresses the precedence of metaphysical principles over material forms in classical Chinese thought. See Zhenfu Zhou, *Zhou Yi* [*Book of Changes*] (Beijing: Zhonghua Book Company, 1991), 250. (in Chinese)

[27] Li Yingke, "中国文化遗产保护思想的发展与实践" [The Development and Practice of Chinese Cultural Heritage Preservation Thought], *Journal of Northwest University (Philosophy and Social Sciences Edition)* 55, no. 1 (2025): 34. (in Chinese)

[28] Li, "The Development and Practice of Chinese Cultural Heritage Preservation Though: 37.

Figure 3.1: Construction scene during the 1983 dismantling restoration of Yueyang Tower. In 1983, Yueyang Tower underwent the largest and most influential overhaul in history. The overhaul was completed the following year, and Yueyang Tower was restored to its original state, reaching the first-class level of ancient building maintenance in China.

Within China's predominantly timber-framed architectural system, this philosophy possessed a more pragmatic foundation. The renewable nature of timber and the cyclical maintenance of structures rendered ‘reconstruction’ a vital means of sustaining cultural continuity. Ancient Chinese scholars regarded the ‘reconstruct ability’ of timber buildings as integral to their cultural vitality, rather than an act undermining authenticity. Some modern scholars also express support for reconstruction.

For instance, Wu Hung contends that ‘though China's ancient timber structures underwent repeated rebuilding, they preserved continuity in form and function’; [29] while Chen Wei observes that ‘even as the physical structure changes, its spiritual essence persists like an unbroken thread.’[30] Within this context, reconstruction is not

[29] Wu Hung, *The Story of Ruins: Presence and Absence in Chinese Art and Visual Culture*, trans. Xiao Yi (Shanghai: Shanghai People’s Publishing House, 2012)：13. (in Chinese)

[30] Chen Wei, “文物建筑保护与文化学——关于整体的哲学” [Cultural Theory and the Preservation of Architectural Heritage: A Philosophy of Wholeness], in *Collected Essays on Architectural History and Theory*, vol. 5, ed. Liu Xianjue and Zhang Shiqing (Beijing: China Architecture & Building Press, 1997):133-138. (in Chinese)

‘forgery’ but a legitimate means of cultural re-enactment; to obstruct this mechanism is to sever the continuity of cultural life.

The deep-rooted foundations of ancient traditional culture and entrenched ideological concepts led to the practice of periodically replacing new materials with old ones during timber structure restoration. Simultaneously, the complete demolition or partial destruction followed by reconstruction symbolize dynastic transitions and epochal shifts. The Forbidden City[31] in Beijing exemplifies this approach. Destroyed and rebuilt countless times, it has never lost its symbolic significance as the seat of supreme power and governance. To this day, the Forbidden City maintains its solemn and majestic status.

In summary, the ancient approach to understanding and handling antiquities established the cultural logic of emphasizing symbolism and continuity within China's traditional conservation practices. Even with the 20th-century introduction of the concept of ‘authenticity,’ China never abandoned its cultural ethos in restoring national timber structures. Architectural restoration was viewed as a process of regeneration rather than an attempt to halt time, providing both philosophical and structural underpinnings for subsequent Chinese heritage conservation. Naturally, this approach also carries inherent drawbacks, which this thesis will explore in its concluding section.

3.2.2 The Modern Reinterpretation of Authenticity: Restoring Old Structures to Their Original State

[31] The Forbidden City, also known as the Palace Museum, has been destroyed many times by fire and war since the Ming and Qing dynasties. For the three main halls alone, there are clear records of seven major reconstructions from the Ming to the Qing dynasties; if the side halls, gate towers, palace gardens, corner towers, etc. are also included, the number of various repairs and reconstructions is more than hundreds of times. It is the palace of 24 emperors of the Ming and Qing dynasties in China.

Figure 3.2: Chinese architect Liang Sicheng investigating a timber roof structure.

The traditional method of restoring ancient Chinese buildings can be described as the traditional Chinese approach of restoration-as-renewal, a practice that aimed to preserve the physical form of the structure so as to maintain its cultural and spiritual continuity. However, this approach often erased historical traces and concealed the building's developmental history. A major shift in this understanding was initiated by Liang Sicheng.[32] Between the 1930s and 1950s, he systematically argued that the "original form" should be regarded as a fundamental element of architectural authenticity, and he promoted—and put into practice—a restoration philosophy based on "restoring the old as it was" (xiu jiu ru jiu).

He argued that the restoration of historic buildings should preserve their original appearance as far as possible, including their structural form, materials, and workmanship. This view was expressed repeatedly in his major works, such as Annotations to the Yingzao Fashi and A History of Chinese Architecture. In the 1940s, Liang Sicheng stated on multiple occasions—both in the Bulletin of the Society for the

[32] Liang Sicheng (1901–1972) was a pioneering architectural historian and educator and a key figure in the documentation of traditional Chinese timber architecture. His field surveys and analytical drawings foregrounded the relationship between original material fabric, replaceable timber components, and the continuity of traditional construction—providing a critical reference for later discussions on authenticity and intervention strategies in the conservation of wooden structures.

Study of Chinese Architecture and in various restoration reports—that "the repair of ancient buildings should follow the principle of restoring the old as it was, striving to reconstruct the original appearance." In projects such as the Beijing city walls, the Hall of Prayer for Good Harvests at the Temple of Heaven, and the Wild Goose Pagodas, he insisted on "restoring the old as it was and preserving the original state," and opposed "innovative imitation in the guise of antiquity."

Faced with cultural and theoretical differences, the Chinese principle of "restoring the old as it was" stands in tension with the international "no reconstruction" doctrine, particularly in determining the acceptable extent of reconstruction.

3.2.3 The Emergence of "Yuanzhenxing" (Original Authenticity) and Its Chinese Interpretation

Since China joined the International Council on Monuments and Sites (ICOMOS) in 1985, it has gradually entered the global conservation discourse. However, Western concepts such as "authenticity" and "minimum intervention" often conflicted with long-standing Chinese practices. To bridge these differences, summarize China's own experience, and respond to international standards, Chinese authorities collaborated with international organizations to draft a local-oriented conservation document in 1999: the Principles for the Conservation of Heritage Sites in China (commonly known as the China Principles).[33]

In 2002, the revised China Principles incorporated the traditional principle of "restoring the old as it was" and formally introduced the term yuanzhenxing (原真性) into all official heritage conservation guidelines. It states: "the original appearance

[33] China ICOMOS, *Principles for the Conservation of Heritage Sites in China*, revised edition (Beijing: Cultural Relics Publishing House, 2015), 12–13.

should be preserved as far as possible, using traditional materials and techniques, with recognizability, reversibility, and minimum intervention." The document also emphasizes that "the aesthetic value of a site derives from its historical authenticity, and its historical condition must not be altered for the sake of visual completeness." [34] Furthermore, it stipulates that "heritage sites must possess historical authenticity." These statements reflect a Western-oriented understanding of historical continuity, emphasizing the entire life cycle of a site rather than restoring only its initial form.

In the Chinese context, yuanzhenxing is a heritage conservation concept that originates from the traditional notion of "restoring the old as it was." It stresses the recognizability and continuity of a heritage site's original form, structure, materials, and craftsmanship. Although yuanzhenxing appears linguistically similar to the Western term "authenticity," it embodies a different set of cultural traditions, conservation philosophies, and practical approaches.

As China's indigenous interpretation of "authenticity," yuanzhenxing combines yuan (original), zhen (true), and xing (state or quality). It therefore refers not merely to the physical reproduction of an original state but to a holistic condition of authenticity that includes craft techniques, functions, cultural meanings, and historical continuity. In this sense, Chinese practice places greater emphasis on cultural and craft recognizability, even when this requires the replacement of certain original materials.

Yet this standard of "whole-process authenticity" faces challenges in traditional conservation contexts, especially in grassroots communities and rural areas, where strict authenticity requirements may be unrealistic due to limitations in resources, labour, and procedural capacity. The Qufu Declaration issued in 2005, [35] based on

[34] Zhu, "China's Architectural Heritage Conservation Movement," 20.

[35] The Qufu Declaration is an academic consensus document adopted at the International Symposium on the Conservation of Cultural Heritage and Ancient Architecture in China, held in Qufu City, Shandong Province, on 30 October 2005. It aims to summarise and clarify the theoretical and practical framework for the conservation and restoration of cultural heritage and ancient architecture with Chinese characteristics. The Declaration emphasises conservation principles such as 'minimal

numerous restoration cases, argues that the essential historical information of a building is often embedded in its structural system—particularly its timber framework. It re-materializes the concept of yuanzhenxing by emphasizing the real physical presence of structure and material, rather than relying solely on the symbolic continuation of traditional craft.

This perspective suggests that preserving cumulative layers of history may be less important than ensuring the complete reproduction of a building's state at a specific historical period when adequate craft documentation exists. The declaration further asserts that the replacement or repair of certain components should not be considered a loss of authenticity; rather, it is a necessary means of sustaining architectural culture and traditional craftsmanship.

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intervention', 'original materials and techniques', and 'continuity of historical information'. It signifies the maturation of China's approach to heritage conservation and establishes a relatively independent developmental trajectory within the international conservation discourse.

Conclusion

By examining international and domestic documents, legislation, and practices, it becomes evident that differing cultural traditions and social contexts yield varied responses and choices regarding questions such as “what should be preserved”, “how to present authenticity”, and “what constitutes truthfulness”. Both China and Italy possess profound timber-framed building traditions. When addressing authenticity within timber-framed systems, their conceptual approaches reveal both divergences and convergences. These responses form the bedrock of restoration theory, determine the direction of technical interventions, and suggest that ‘authenticity’ is not a static definition but a concept continually redefined within different structural systems and cultural logics.

For instance, Paolo Marconi's Italian restoration philosophy exhibits surprising conceptual resonance with China's Qufu Declaration. Marconi emphasizes that restoration must respect historical authenticity while preserving the holistic relationship between buildings and their cultural environment, advocating for integrated conservation. He contends that heritage values reside not solely in physical form but is embodied within its interconnected social, cultural, and environmental contexts. Similarly, the Qufu Declaration proposes that cultural heritage should be protected as an organic whole, stressing the intrinsic connection between historic buildings and their cultural landscapes and living traditions. This convergence of ideas reflects a shared understanding of ‘authenticity’ emerging from distinct cultural contexts in China and Italy – a shift from material authenticity centered on physical elements towards ‘holistic authenticity’ focused on cultural continuity and integrated relationships. Both seek to strike a balance between tradition and modernity, ensuring heritage retains its vitality while remaining a true witness to history.

Concurrently, as analyzed in Part One, China and Italy have developed distinct, culturally specific responses to the international theoretical framework of ‘authenticity’. China's localized research emphasizes ‘cultural continuity’ and symbolic representation, while Italian scholars propose prioritizing the ‘integrity of structural systems’ over the physical preservation of original components. These concepts transcend theoretical discourse, manifesting in concrete restoration practices through assessments of structural conditions and interventions.

However, when confronting authenticity theories modelled on stone masonry, both nations' restoration practices reveal inherent theoretical tensions. The root cause lies not merely in cultural traditions or material differences, but in the inherent structural logic and joint construction characteristics of timber frameworks. This ‘frame-connection’ core system possesses dynamism and interchangeability, inherently conflicting with the authenticity assumption of ‘material permanence’. Consequently, despite belonging to distinct cultural contexts, China and Italy face similar challenges and develop respective responses in adjusting their timber restoration philosophies.

Part II: Structural Logic and Node Construction of Timber Systems

The conservation and restoration of timber structures rely not only on material-level research but critically on a profound understanding of their holistic structural logic and mechanical properties.[36] Theoretically, scholars from both China and Italy have addressed the applicability of 'authenticity' within the timber context. Yet these principles transcend abstract discourse, manifesting through concrete restoration practices—specifically in the assessment of structural conditions and the selection of intervention pathways.

In the theoretical analysis of the first section, China and Italy belong to distinct value systems in their approaches to heritage restoration. The former emphasizes "cultural continuity" and symbolic representation, while the latter upholds "authenticity" and prioritizes material preservation. Scholars from both nations have addressed the applicability of 'authenticity' within timber-framed contexts. Yet these principles transcend theory, manifesting in practical restoration through structural assessments and intervention strategies.

This thesis centers on how conservation philosophies translate into tangible restoration actions, fundamentally grounded in the feasibility and constraints dictated by architectural structural logic. The timber structure, particularly the roof systems in traditional buildings, serves as the tangible arena where these principles are implemented. Beyond bearing physical loads, timber roof systems embody multiple functions: structural craftsmanship, cultural symbolism, and aesthetic ideals. Their joint configurations, renewal mechanisms, and craft logic define both the scope for choice and the constraints within restoration. In essence, principles do not unilaterally dictate

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[36] Jorge M. Branco and Ivan Giongo, "Special Issue on 'Existing Timber Structures'," *International Journal of Architectural Heritage* 12, no. 4 (2018): 505.

technical approaches; rather, they seek “feasible solutions” that reconcile structural feasibility with cultural orientation.

Therefore, this chapter will adopt a structural perspective, focusing on the critical level of the roof system to analyze the structural logic and connection systems of timber-framed buildings. It will elucidate the differences between Chinese and Italian timber-framing traditions through comparative examination. The research will further demonstrate that distinct structural logic often corresponds to different damage progression mechanisms, while varying connection methods directly influence the feasibility and limitations of subsequent interventions.

Chapter 4 Structural Characteristics and Node Details of Timber Systems in China

4.1 General study of The Traditional Chinese Timber System

Traditional Chinese architecture is primarily characterized by timber construction, which developed into an independent and continuous building system that has spanned several millennia of architectural history. Although in the modern era new structural systems such as brick–concrete and reinforced concrete were introduced, influenced by Western architectural models and the pursuit of national development, China did not establish a new indigenous style of its own. Consequently, traditional timber construction has retained a highly representative role within Chinese architecture. Its forms display consistency and orderly variation, while its structural methods and craftsmanship have been transmitted from generation to generation.

As Lin Huiyin stated in the preface to *The Qing Structural Regulations* (*Qing shi yingzao zeli*):

"*Chinese architecture constitutes an independent system of the East. Over thousands of years, it has been inherited and transformed, spreading across vast regions… Even in its mature stages and in its subsequent developments, it has continued to preserve its inherent structural methods and spatial arrangements; it has never lost its original character, thus forming a most distinctive, enduring, and dignified architectural system.*"[37]

Therefore, from the perspective of structural composition, traditional Chinese

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[37] Lin Huiyin, "Introduction," in *Qing shi yingzao zeli* [Qing Architectural Standards], edited by Liang Sicheng (Beijing: Society for Research in Chinese Architecture, 1934), chap. 1. (in Chinese)

timber architecture has undergone no major changes and is generally composed of three systems: The platform base, the roofing system. (Figure 4.1) and the building body (including the wall system, the timber structural frame (Figure 4.2), and timber joinery such as doors and windows.[38]

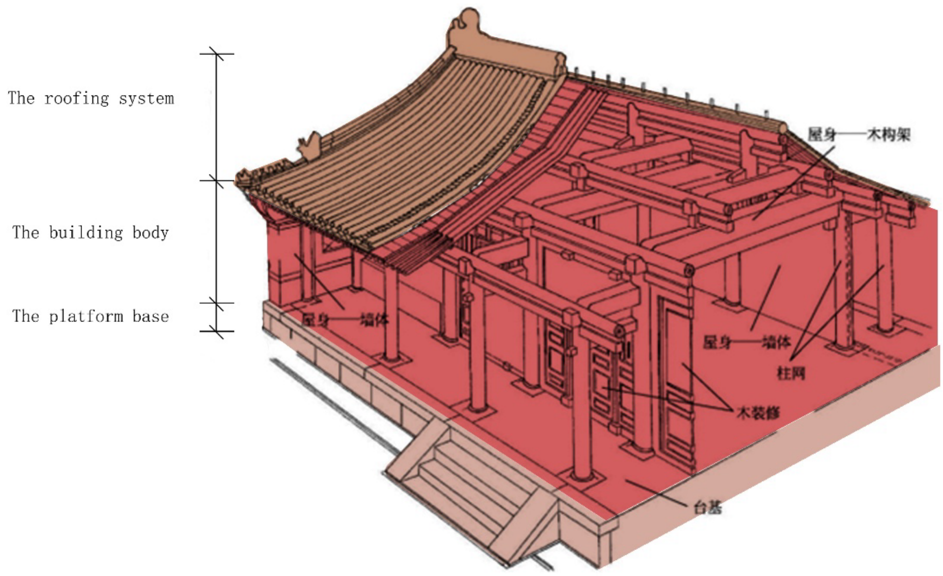

Figure 4.1: Analytical diagram showing the tripartite structural system of traditional Chinese architecture: the roofing system, the building body, and the platform base.

- **Platform (*taiji*)**: Generally constructed of brick, stone, or rammed earth, the platform supports the superstructure while also serving to protect against dampness and seismic activity, and to articulate spatial hierarchy.

- **Roof system**: Positioned above the roof frame, it typically consists of tiles, ridge elements, and other covering layers. Beyond its protective function, the roof also expresses hierarchical status and symbolic meaning through variations in form. Its structural complexity and high visibility make it the most frequently

[38] Wu, Guoyuan, Cai Nan, and Li Lubin. "Study on Structure, Construction and Spatial Correlation of Ancient Chinese Architecture." *Journal of Xi'an University of Architecture & Technology (Natural Science Edition) * 55, no. 6 (2023): 106–112. (in Chinese)

restored part of traditional architecture. Different roof types not only signify different architectural ranks and functions, but also directly influence the configuration of the roof frame, the treatment of joints, and the level of technical difficulty in later restoration, thus representing a critical variable in conservation interventions.

- **Timber framework system** (Figure 4.2): This consists of two components, the column grid and the roof frame. The column grid, formed by columns and tie beams (*fang*), provides the vertical skeleton; the roof frame, composed of beams, purlins, and rafters, constitutes the structural unit supporting the roof. These two subsystems are connected through mortise-and-tenon joints, creating a stable and continuous load-bearing system.

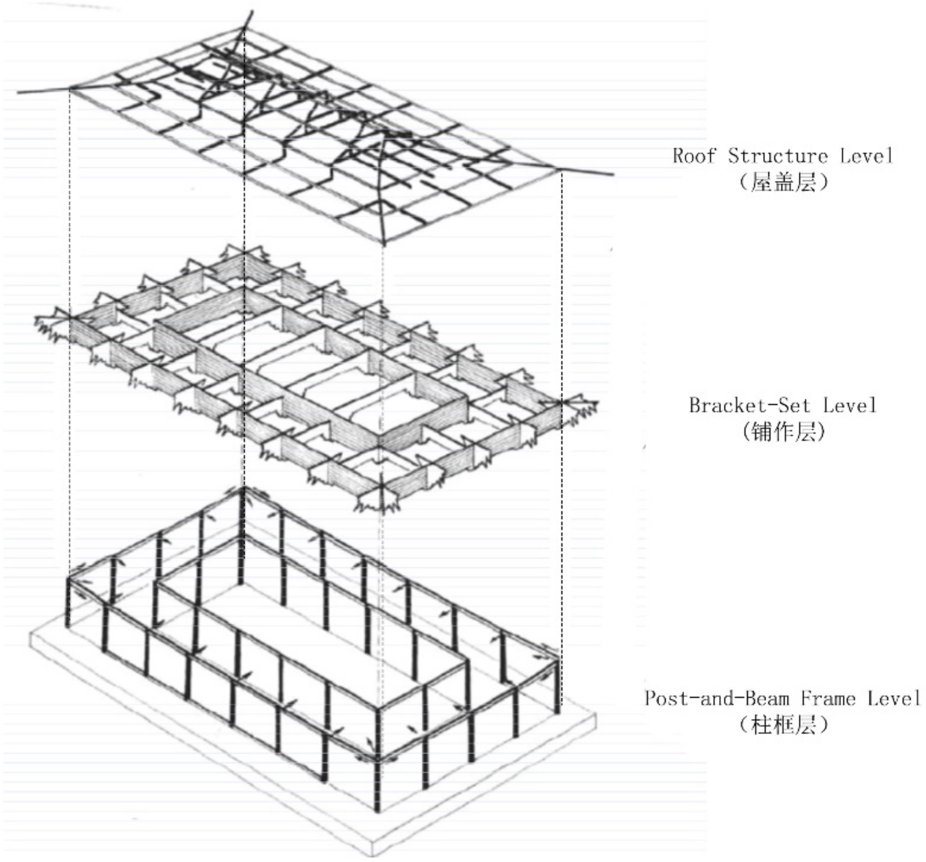

Figure 4.2: Schematic diagram of the layered wooden frame of the Main Hall of Foguang Temple, Wutai Mountain, Shanxi.

From the perspective of structural development, ancient Chinese basic construction is generally classified into three categories: Post-and-lintel Wooden Framework, Column-and-tie Wooden Framework and Log Cabin Wooden Framework.[39]

The Log Cabin Wooden Framework (Figure 4.3) consists of horizontal stacking of timbers to form load-bearing walls, relying primarily on the compressive strength of the wood's transverse grain.[40]

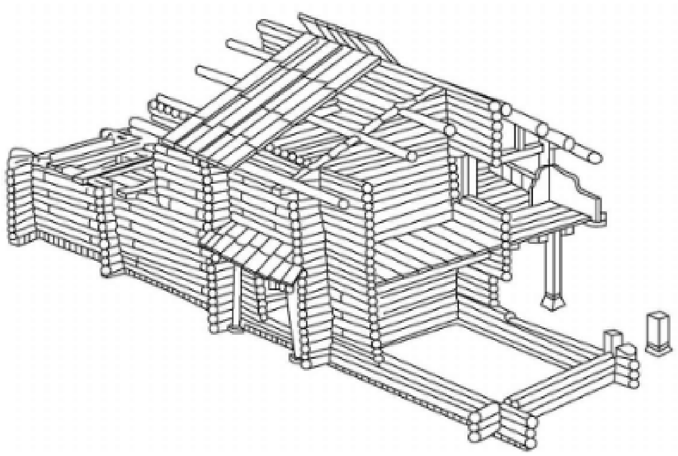

Figure 4.3: Model and structural schematic of the log-cabin wooden framework (jinggan style), traditionally used in ancient Chinese timber construction.

From the perspective of load-bearing systems and structural logic, the Log Cabin Construction lacks an independent column-beam framework system, and its structural mechanism differs from timber-frame systems characterized by skeletal load bearing. For the purposes of analyzing structural logic, connection methods, and repair interventions in this paper, the following discussion treats the Log Cabin Construction as a distinct load-bearing timber wall type, while Post-and-lintel Wooden Framework and Column-and-tie Wooden Framework as the primary wooden framework construction under examination.

[39] Zhang Yao, Sunmao de meili [The Charm of Mortise and Tenon] (Beijing: China Architecture & Building Press, 2015), 35. (in Chinese)

[40] Ibid., 40.

4.2 Classification and Characteristics of the Wooden Framework Construction

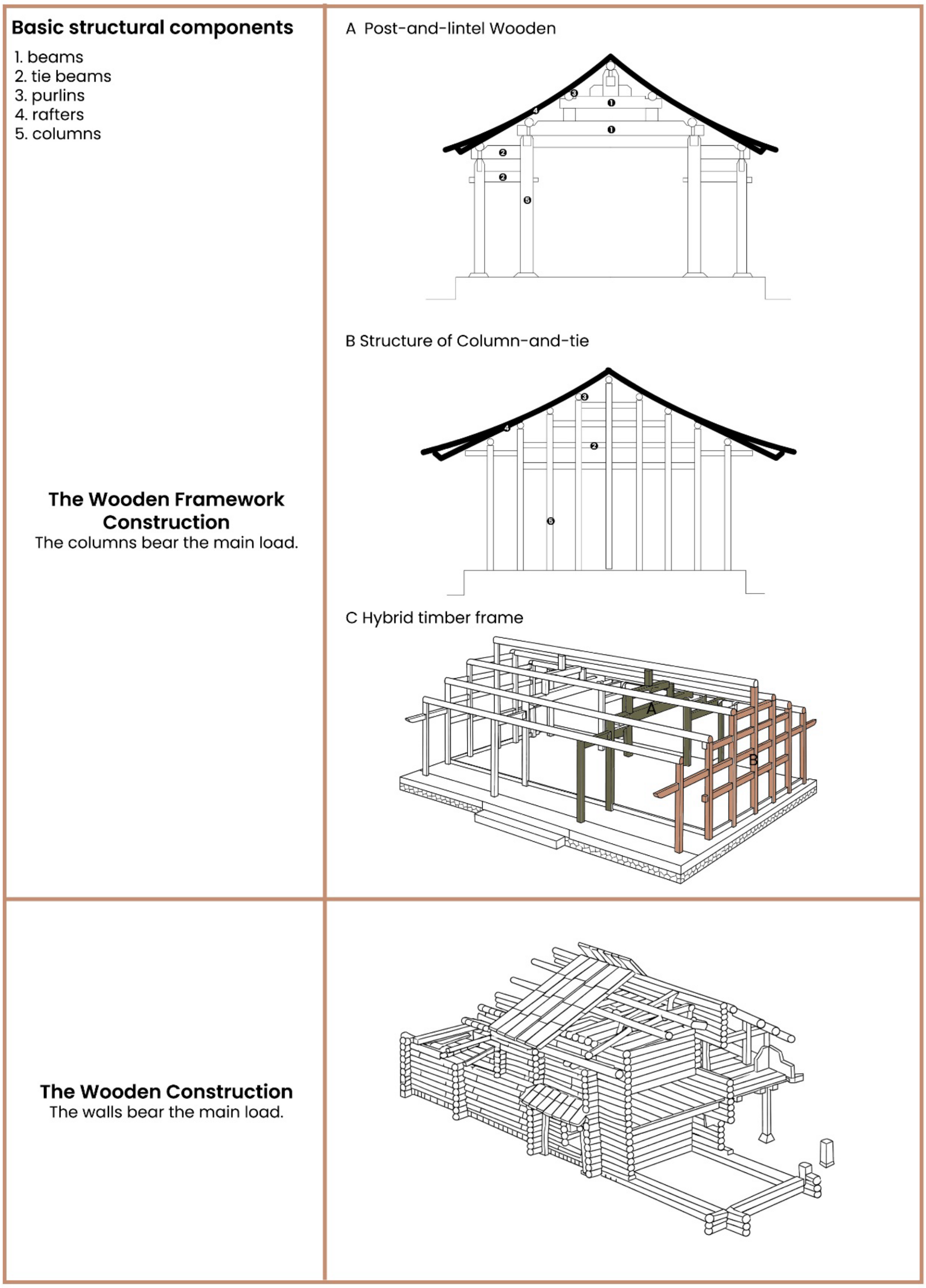

Figure 4.4: Diagram Classifying the Wooden Framework Construction

Within timber-framed construction, scholars such as Liang Sicheng and Liu Dunzhen[41] identify the post-and-lintel wooden framework and the column-and-tie wooden framework as the most important types.[42] Those systems became the dominant form of traditional Chinese architecture, widely employed in palaces, temples and residential architecture.

4.2.1 Post-and-lintel Wooden Framework

Post-and-lintel construction (Figure 4.5) is the most common form of timber structural system in China. It first appeared during the Spring and Autumn Period and reached maturity in the Tang dynasty. This system was widely used in large-scale buildings such as palaces, temples, monasteries, as well as in traditional vernacular architecture in northern China.

In the spatial framework of the house with double sloping roof, the adjacent two sets of wooden frameworks relate to transverse tie beams and purlins, and the purlins relate to rafters. From a spatial perspective, the post-and-lintel arrangement positions the columns along the periphery, allowing beams to span considerable distances and thereby creating expansive interior spaces.

Post-and-lintel construction consists of pillars, beams, purlins, tie beams（fang） and other basic components. In this structure, pillars are erected on the foundation, beams are set on the pillars, and then several layers of short pillars and beams are overlapped on the beams. From the bottom to the top, as the height increases, the length

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[41] Liu Dunzhen (1897–1968) was a pioneering Chinese architectural historian and educator, recognized as one of the “Five Masters of Modern Chinese Architecture,” along with Liang Sicheng. He made foundational contributions to the study and preservation of traditional Chinese architecture.

[42] Lu Weidong, Deng Dali, Lü Xingpeng, Cheng Xiaowu, and Yang Huifeng, “Zhongguo mu jiegou jianzhu fenbu ji qi zhenhai” [Distribution and Seismic Damage of Timber Structures in China], Journal of Xi’an University of Architecture and Technology (Natural Science Edition) 43, no. 4 (2011): 464. (in Chinese)

will be shorter layer by layer. Finally, there is a king post on the top, forming the entire wooden framework.[43]

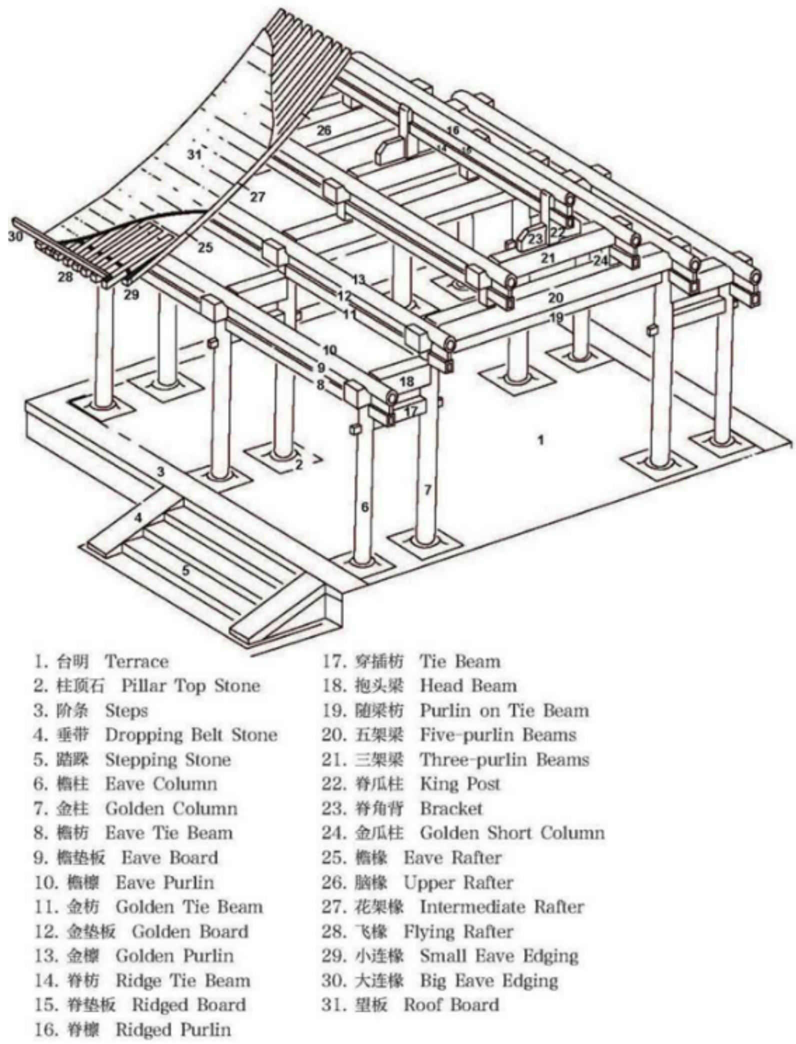

Figure 4.5: Structural system of the post-and-lintel timber framework (tailiang style), featuring ridge beams, king posts, and multiple horizontal components.

Therefore, from the standpoint of load-transfer mechanisms (Figure 4.6), roof loads are transmitted successively from the rafters and purlins to the beams, then from the beams to the columns, and finally to the foundations, which represents a typical frame-type structural behavior. The dominant stress state is characterized by beams

43 Zhang Yao, *Sunmao de meili*, 35-40.

working primarily in bending and columns mainly in axial compression. Since bending in the beams governs the system response, the overall vertical stiffness is relatively low, and the structure is more sensitive to deflection and long-term deformation.

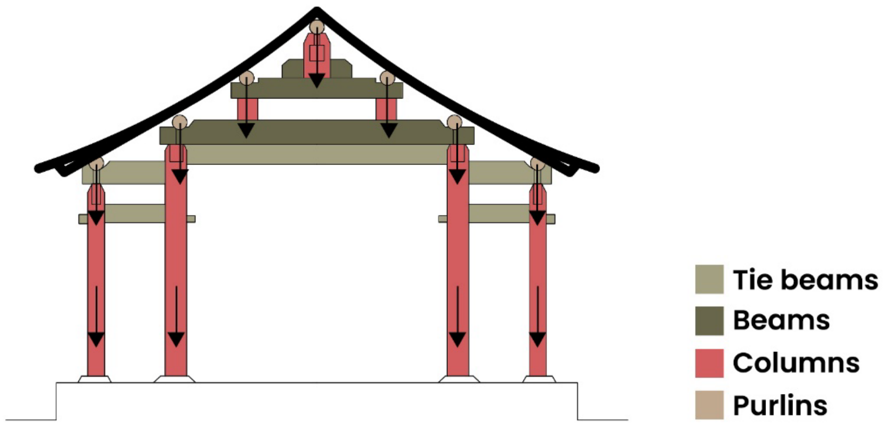

Figure 4.6: Structural system of the post-and-lintel timber framework

From a mechanical perspective (Figure 4.6), under static conditions, the transmission of gravitational forces is always vertically downward; consequently, this structure can withstand considerable pressure without requiring reinforcement techniques.

Simultaneously, the deformation control and durability-related vulnerabilities of the post-and-lintel system tend to concentrate on beam deflection and on the bearing interface at the beam ends. Under the combined effects of cracking, insect attack, or cumulative long-term deflection, local crushing at the beam supports, moisture-related decay, and progressive loosening of beam–column joints may occur, thereby reducing geometric stability and overall structural performance.

Consequently, in terms of material selection and structural detailing, primary beams are typically designed with relatively large cross-sections to carry the main vertical loads. At the same time, the beam-end bearing zones and beam–column joints should be treated as priority areas for subsequent inspection, maintenance, and conservation interventions.

4.2.2 Column-and-tie Wooden Framework

Column-and-tie Wooden framework (Figure 4.7) became mature no later than the Han Dynasty and was widely applied in the dwelling houses in south China.

Column-and-tie Wooden framework consists mainly of columns, purlins, crossbeams and cantilevers. Its construction is to set up columns in the depth's direction of the house. Each column has a purlin on the top, then rafters are set on the purlins, and the roof load will be transmitted directly from purlins to columns. Each row of columns is transversely penetrated by penetrating tie beams, forming a frame. [44]

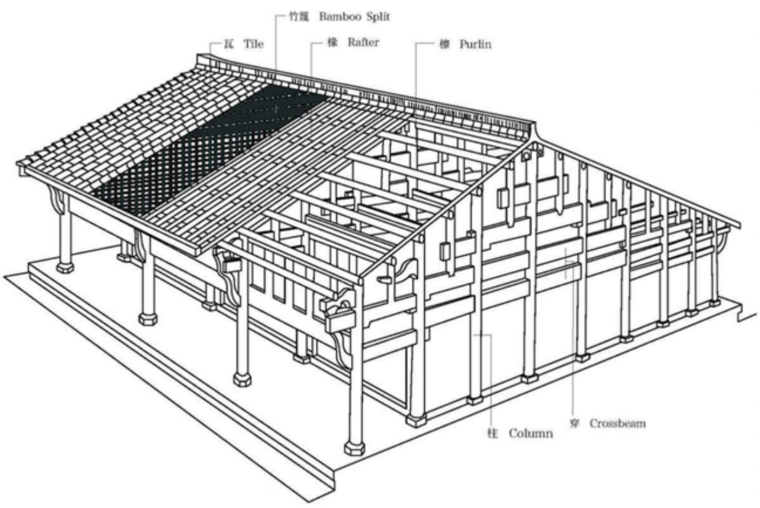

Figure 4.7: Axonometric and sectional views of the column-and-tie timber framework (chuandou style), characterized by its stacked columns and transverse beams.

Therefore, from the standpoint of load-transfer mechanisms (Figure 4.8), roof loads in the column-and-tie system are conveyed primarily through a denser network

[44] Ibid., 39.

of vertical members. After being distributed by horizontal linking elements—such as tie members and transverse beams—the loads are transferred relatively directly into the columns and then down to the foundations. Unlike the post-and-lintel system, which is governed by beam bending, the column-and-tie system exhibits a more column-dominated behavior: the principal load-bearing members work mainly in axial compression, while horizontal members play a secondary role in tying the framework together, distributing loads, and ensuring overall stability, thus forming a continuous vertical load path.

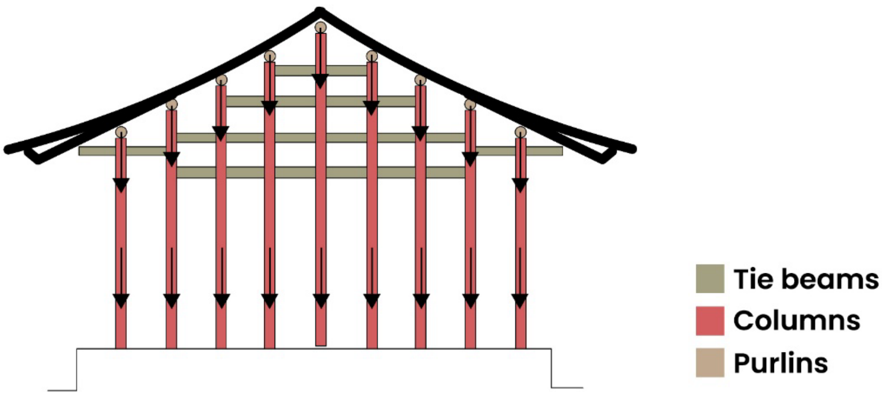

Figure 4.8: Structural system of the column-and-tie timber framework

From a mechanical perspective, deformation control and durability-related vulnerabilities in the column-and-tie system tend to concentrate on the continuity of the column lines and the performance of their connections. On the one hand, column bases and bearing interfaces are susceptible to moisture-related decay or local crushing, which may trigger differential settlement and progressive global out-of-plumb deformation. On the other hand, long-term loading and environmental effects may lead to wear, loosening, and slip at column–tie joints, reducing lateral stiffness and accelerating the accumulation of deformation. Consequently, inspection and conservation priorities should focus on column bases and bearing zones, column–tie connections, and key linking members. Any intervention should be carefully calibrated in terms of stiffness and restraint, so as to avoid altering established load-transfer mechanisms or introducing local over-stiffening that could induce unintended load redistribution.

From a spatial perspective, the post-and-lintel framework employs a series of columns and horizontal tie-beams interconnected between each pair of frames to form the room's spatial structure. This allows for the construction of larger buildings using relatively fewer materials, whilst its lattice-like construction proves remarkably robust. Consequently, the advantage of the timber post-and-beam framework lies in its reduced material and timber consumption. However, due to the greater number of posts and beams, it cannot create large, uninterrupted interior spaces.

4.3 Structural Logic of Joints in Chinese Wooden Framework Construction

Structurally, despite diverse construction techniques and types, traditional Chinese timber structures consistently maintain a high degree of modularity and systematization in their overarching logic. The timber framing system of ancient Chinese architecture—centered on the principle of "load-bearing skeleton with added enclosures"—forms a self-supporting structural framework composed of columns, beams, purlins, and other components.[45] As vividly illustrated by the northern Chinese proverb "walls may fall, but the house remains standing," this structure exemplifies the load-bearing characteristics of timber framing.

As mentioned earlier, the timber framework of Chinese architecture typically comprises fundamental components such as columns, beams, crossbeams, purlins, bracket sets, and rafters. These elements are independent and require connection

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[45] Ma Bingjian, "Zhongguo mu gou jianzhu de tedian he kexue baohu" [Characteristics and Scientific Conservation of Traditional Chinese Timber Architecture], *Sciences of Conservation and Archaeology* 21, no. 1 (2009): 9. (in Chinese)

through mortise-and-tenon joints to form a structure.

Simultaneously, mortise and tenon joints assemble disparate components into nodes, which serve as pivotal junctures within the entire structural framework. Should these junctures lose their connection, the edifice risks collapse.

Therefore, this subsection shall focus on analyzing the operational mechanism of mortise-and-tenon joints from a structural mechanics perspective, examining their position and function within the overall structure. It shall further explore the potential damage patterns that may arise in mortise-and-tenon joints under varying loading conditions and their impact on structural performance.

4.3.1 Mortise-and-Tenon Connections

Consequently, the mortise-and-tenon joint constitutes the fundamental characteristic of ancient Chinese timber construction systems and represents the earliest scientifically significant design language within Chinese architecture.[46]

A wide variety of mortise-and-tenon configurations exists, tailored to different structural roles and detailing conditions（Figure 4.9）. In practice, craftsmen did not select joint forms solely based on local strength requirements; they also accounted for the position of members within the framework and, crucially, for the assembly sequence through which components overlap and lock into place. This construction logic highlights that joint performance in Chinese timber structures depends not only on geometry, but also on the controlled organization of installation and dismantling.

[46] Zhang Yao, *Sunmao de meili*, 23.

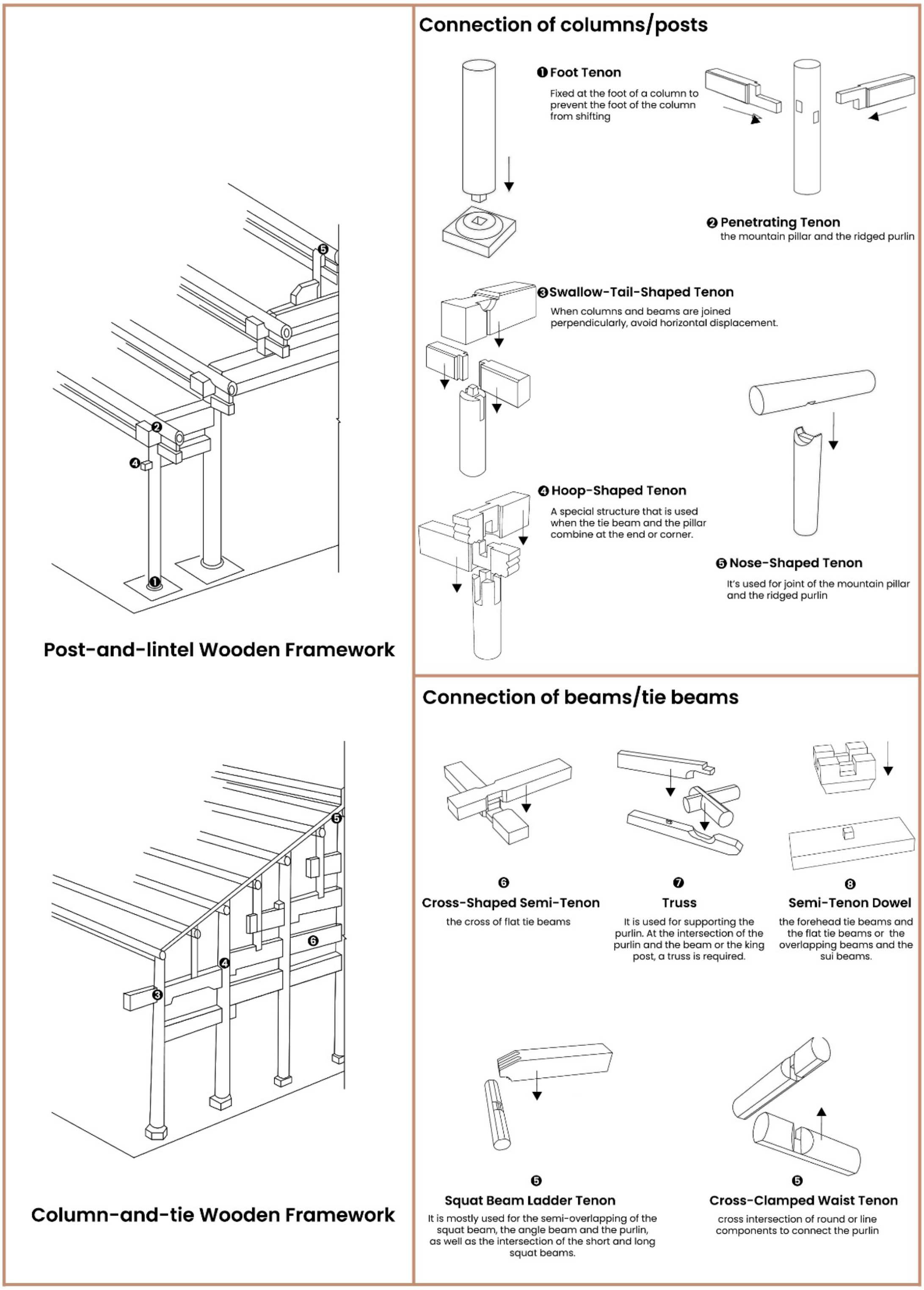

Figure 4.9: Diagram of Types and Locations of Mortise and Tenon Joints

From a mechanical perspective, mortise-and-tenon joints are neither rigid connections nor fully hinged, but rather semi-rigid connections possessing distinct force directionality and finite constraint capacity. Their mechanical performance relies primarily on the geometric configuration of components, contact area, and the clamping and frictional interaction between elements, rather than the tensile or bending strength of any single component. Consequently, within structural systems, mortise-and-tenon joints primarily bear compressive and shear forces while permitting a degree of rotation and sliding to accommodate structural deformation and environmental loads.

Taking column-related joints as an example (Figure 4.9), their principal mechanical function lies not in rigid fixation but in ensuring stable column positioning while restricting horizontal displacement. For instance, Swallow-Tail-Shaped Tenons and Hoop-Shaped Tenons enhance shear resistance through geometric interlocking. Such joints primarily endure compression and shear forces, with tensile loads not being a design objective. Joint stability relies upon component self-weight, compression effects, and contact friction.

4.3.2 Node and potential damaged conditions

Through mortise-and-tenon joints, a timber-framed structure can be divided into four principal types of connection: Pillar-End Node, Pillar-Head Node, Pillar-Body Node, and Beam-Purlin Node (Figure 4.10).[47]

These four types of joints constitute the critical load-bearing junctions within timber-framed structures. Deterioration in joint connections alters the structure's load transfer pathways and compromises overall stability. This chapter examines the structural function of various mortise-and-tenon joints from a mechanical performance perspective, discussing the impact of defects such as rotation and cracking on joint integrity, alongside contemporary restoration practices.

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[47] Ibid., 41.

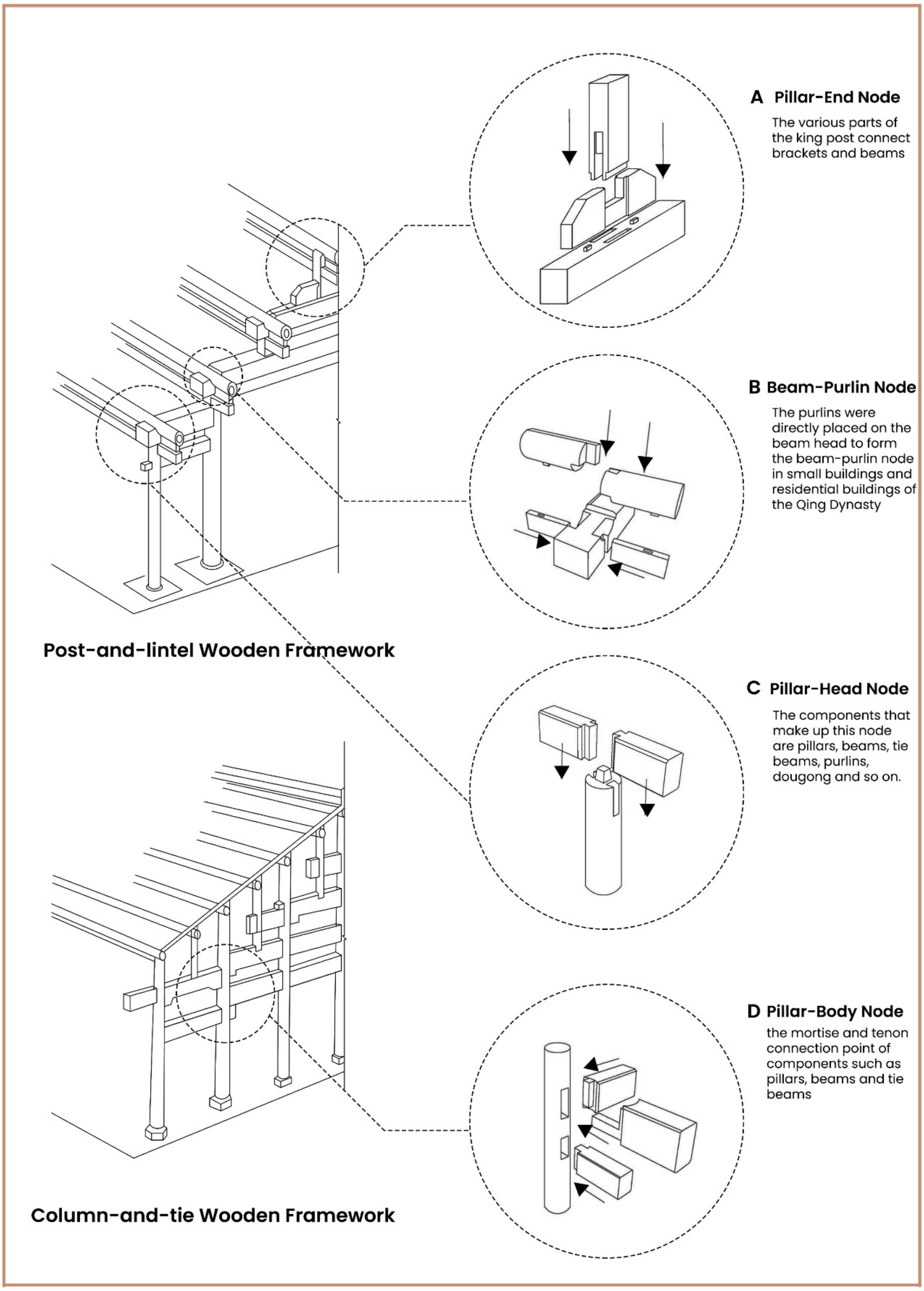

Figure 4.10: Diagram of Types and Locations of Node

(A) The pillar-end node (Figure 4.11) does not constitute the connection between the column base and the foundation, but rather the joint between the king post set upon the beam and the lower load-bearing beams. Its primary function is to transmit vertical loads from the ridge or purlins to the beam framework system. This node primarily experiences compressive forces, with shear forces being secondary, and essentially bears no tensile loads.

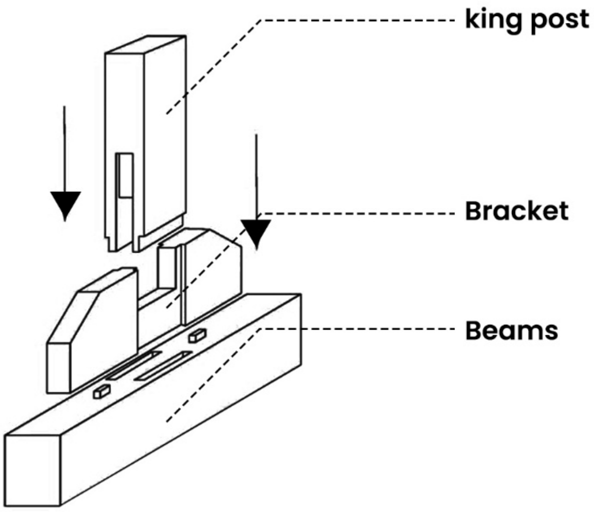

Figure 4.11: Illustration of Pillar-End Node

The brackets installed at column-to-beam joints serve not merely as ornamentation but primarily to regulate the stress relationship between short columns and lower beams. By enlarging the bearing contact area, these components reduce local compressive stresses, thereby preventing beam surface crushing and premature joint degradation. Concurrently, brackets assist in correcting the transmission path of vertical loads, ensuring axial pressure is distributed more uniformly to the lower beams.

(B) The Beam-purlin node primarily bears local compressive stresses and shear force transfer between bending members, constituting one of the most susceptible locations for slippage and joint degradation within roof systems. In small buildings and residential buildings of the Qing Dynasty, the purlins were directly placed on the beam head to form the beam-purlin node.

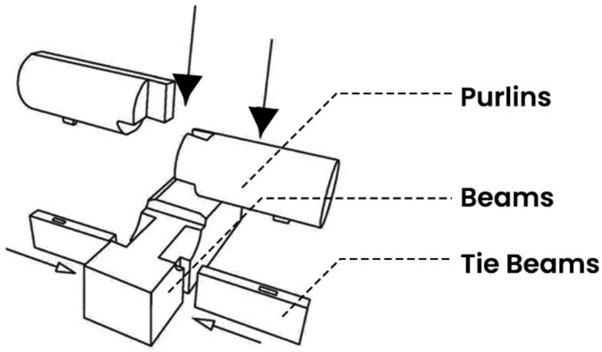

Figure 4.12: Illustration of Beam-Purlin Node

The beam–purlin node restrains vertical displacement and partially restrains horizontal sliding, while allowing rotation and providing no tensile restraint.

(C) The pillar-head node is the most important and critical node of the architectural framework. The load in all directions is transmitted to the plinth through this node.

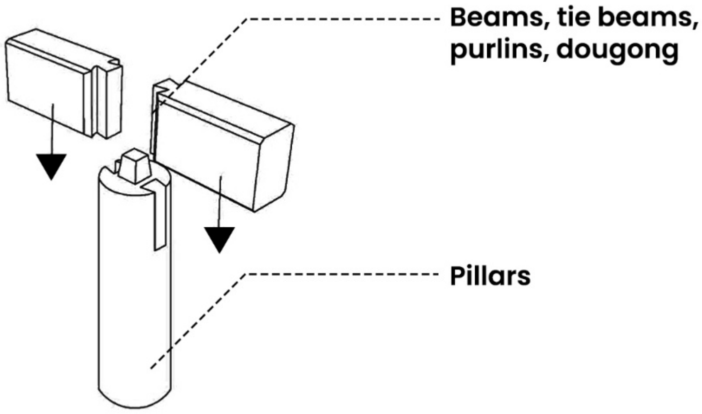

Figure 4.13: Illustration of Pillar-Head Node

Accordingly, this also represents a crucial juncture in subsequent restoration research. In terms of damage distribution, rotting in timber elements[48] often initiates at member ends, particularly at beam and purlin bearings or at interfaces with masonry

[48] The phenomenon whereby microorganisms such as fungi and bacteria erode the internal material of timber components.

and joints (Figure 4.14). These areas are more prone to moisture accumulation, limited ventilation, and local stress concentration.[49]

Figure 4.14: Photo of beam rotting

In contemporary conservation practice, the repair strategy for decayed timber components should be based on a careful assessment of the extent of deterioration and on the structural role of the component within the overall load-transfer system. In general, when decay is limited in area and shallow in depth (for instance, affecting less than approximately one third of the member's cross-sectional height), local removal followed by timber patching, infilling, or partial replacement may be adopted to restore the effective section and local load-bearing capacity. When the decayed area is more extensive, but a sufficient residual section remains, localized reinforcement—such as the use of timber plates, steel plates, or supplementary supports—is often required to satisfy strength and deformation control criteria. By contrast, when decay has significantly reduced the effective section (e.g. exceeding two thirds of the member height) or when the remaining section no longer meets service requirements, end replacement or even complete substitution of the component may become unavoidable.

However, current repair practices are still largely oriented toward restoring node

[49] Yunhong Hao, Zhonghe Yao, Rigen Wu, and Yuanyuan Bao, "Damage and Restoration Technology of Historic Buildings of Brick and Wood Structures: A Review," *Heritage Science* 12 (2024): 17.

integrity and structural performance. From the perspective of authenticity, such interventions are not fully reversible and inevitably affect the material authenticity of the original fabric, particularly through the introduction of new materials and interfaces that alter the historical continuity of the timber components.

(D) The pillar-body node is the mortise and tenon connection point of components such as pillars, beams and tie beams.[50] From a mechanical perspective, the pillar-body node is predominantly subjected to axial compression and plays a critical role in maintaining the continuity of the column as a load-bearing member.

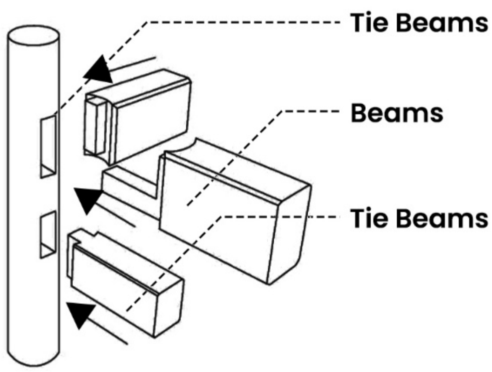

Figure 4.15: Illustration of Pillar-Body Node

Beams, purlins, rafters and other transverse timber members primarily resist bending and shear, and the assessment of cracking in these components is therefore closely related to crack width, depth and its influence on load-bearing capacity.

In contemporary restoration practices, cracks are categorized by width into mild, moderate, and severe classifications, with complete component replacement reserved for the most critical cases.[51] Repair methods commonly employ timber inserts or metal reinforcement, aiming to preserve as much of the original, undamaged structure as possible while maintaining reversibility and sustainability. However, the application of these techniques often involves substantial use of metal components, which can readily

[50] Zhang Yao, *Sunmao de meili*, 43.
[51] Hao et al., "*Damage and Restoration Technology of Historic Buildings*," 19.

compromise the visual integrity of historic buildings. In recent years, research teams have also explored novel materials as alternatives to metal reinforcement.[52]

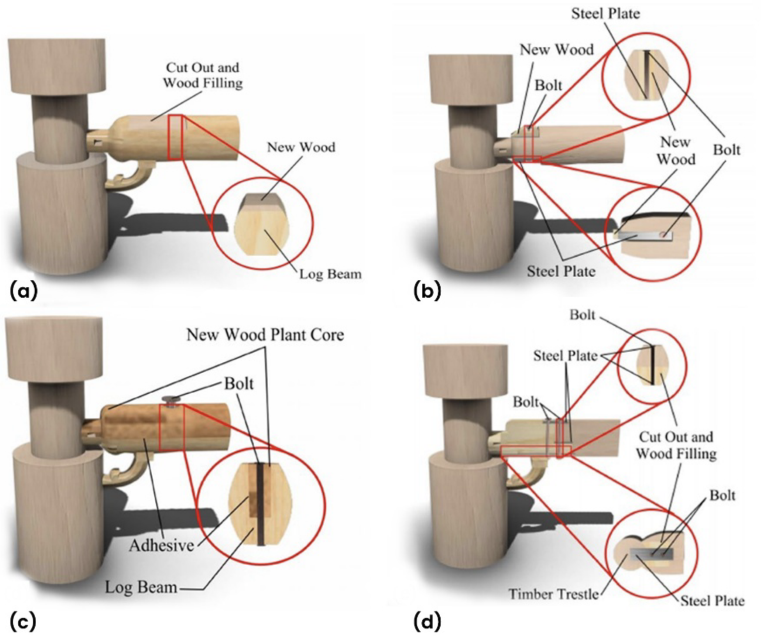

Figure. 4.16: Schematic diagram of crack repair of beam and tie-beam.

(a) Embedding method (b) Built-in core material method (d) Roof support method (e) Mechanical reinforcement method

4.3.3 Dougong

At the node lies a crucial structural element—Dougong (Figure 4.18). Frequently found in northern official architecture, it not only defines the roof's form but also serves a vital structural function.

Due to the material selection and joint characteristics of the beam-and-post system mentioned earlier, the overall structure tends to be heavier with relatively fewer joints. Under extreme lateral forces, if insufficient support is provided, its stability may

52 Campilho R, De Moura M, Barreto A, Morais J, Domingues J. Experimental and numerical evaluation of composite repairs on wood beams damaged by cross-graining. Constr Build Mater. 2010;24(4):5317.

sometimes be inferior to that of the grid-like distributed post-and-lintel system. Consequently, in official northern architecture, this deficiency was addressed by augmenting the dougong system and employing substantial wall thicknesses.

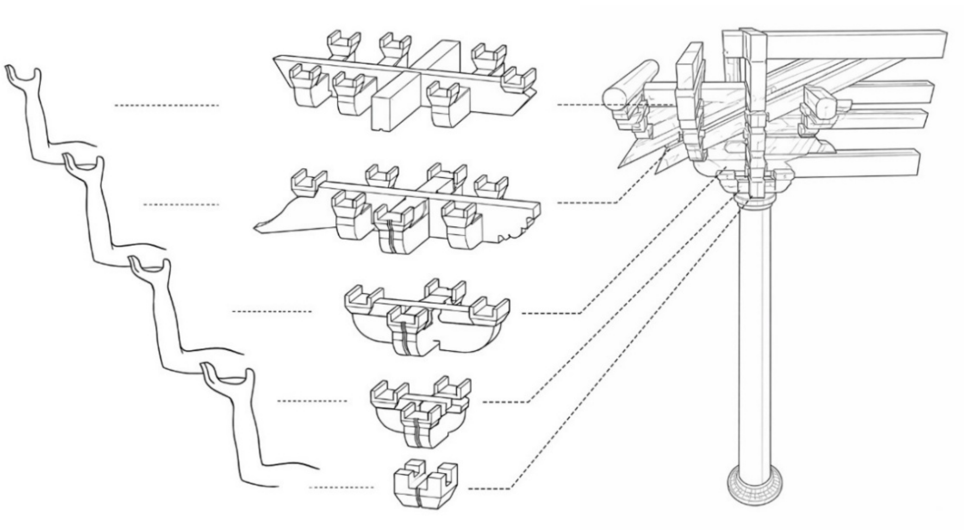

Figure 4.18: Model of Pillar-Head Dougong of the Tang Dynasty

More specifically, dougong achieves the decomposition and redistribution of vertical loads through the layered stacking and mortise-and-tenon connections of its components. This expands the bearing surface area and mitigates stress concentration at the column heads.

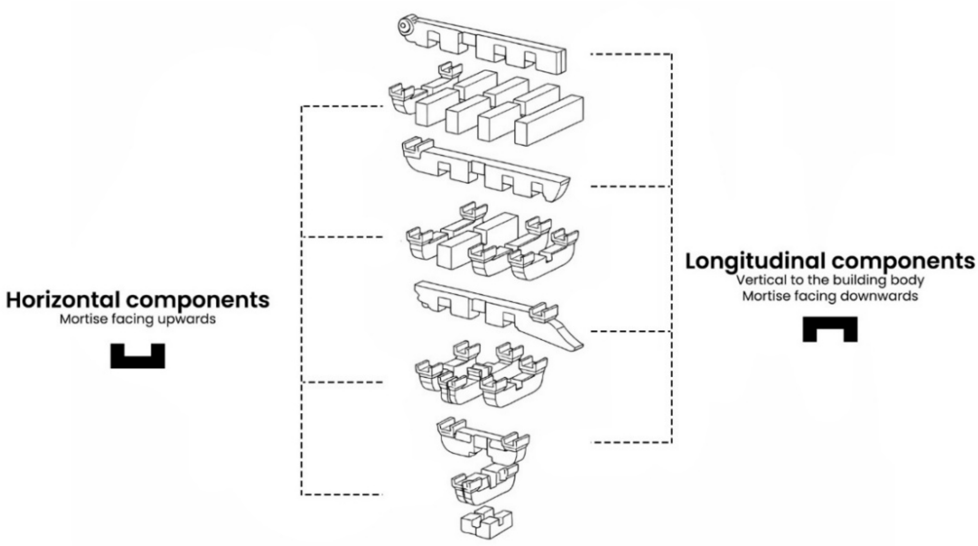

Figure 4.19: Directional Diagram for Dougong Components

At the same time, the dougong may be understood as a labor-saving lever system developed based on empirical knowledge of statics. From a mechanical perspective, the dougong can be idealized as a cantilever system, in which each overlapping component operates according to a lever principle, with the center of the small block (dou) at the projecting end acting as an intermediate fulcrum.

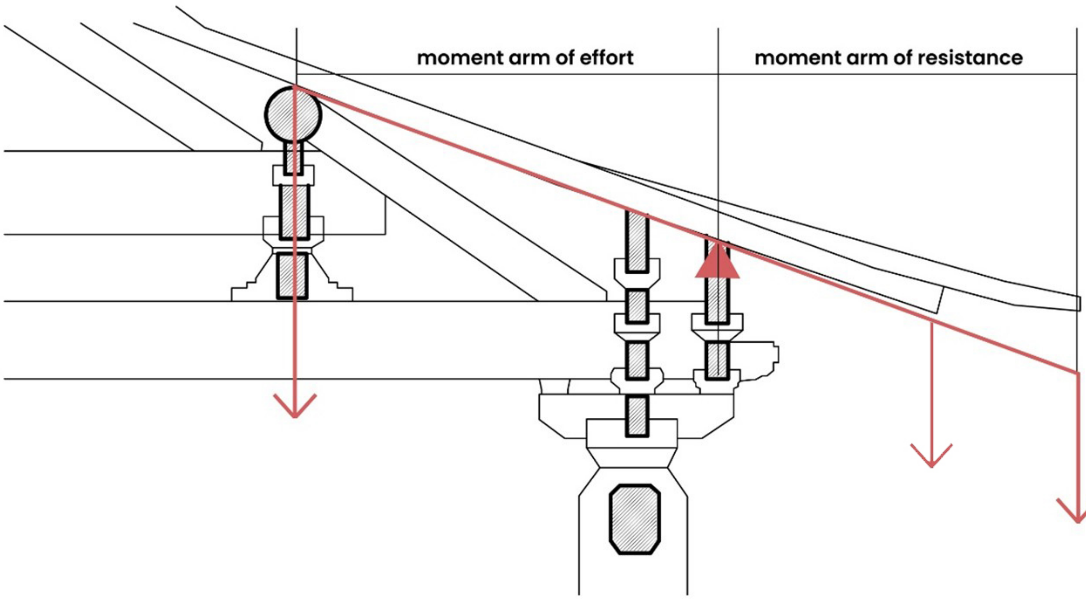

Figure 4.20: Static interpretation in the dougong system

As illustrated in Figure 4.20, in the dougong–eave-rafter configuration, an increase in the number of projecting tiers corresponds to a progressive outward shift of the effective support point. This, in turn, provides greater geometric allowance for the extension of the eave rafters, enabling larger roof overhangs.

Such structural characteristics directly influence the spatial qualities of traditional architecture. For example, in Tang-dynasty buildings, for instance, bracket sets are often larger and more pronounced, enabling deep roof overhangs and reinforcing the monumentality of the architecture as well as its hierarchical representation.

4.3.4 Modulus and Proportional rules

In the previous sections, the composition of timber buildings, the connection methods, and the mechanical behavior of joints define the basic structural form of Chinese timber architecture.

It is also important to note that the long continuity of Chinese timber architecture, with relatively limited formal variation, is not accidental. Behind this continuity lies a stable construction system. From the Tang, Song, Liao, and Jin dynasties to the Yuan, Ming, and Qing periods, and even into later practice, timber buildings were generally constructed according to a unified system of architectural modules and proportional rules. This system was formulated and codified in classical technical texts, most notably the Yingzao Fashi[53] of the Song dynasty and the Gongbu Zuofa[54] of the Qing dynasty.

The module served as the basic unit of measurement for the overall building and for individual components. In the Yingzao Fashi, the fundamental unit was the "cai", which controlled the dimensions of structural members. In the Gongbu Zuofa, the basic controlling units were the doukou and the diameter of the eave column, which functioned as key reference dimensions for both components and overall form.

In traditional construction, strict hierarchical rules governed architectural scale and form. These rules applied not only to building complexes and single structures, but also to bay width, platforms and balustrades, bracket sets, roof tiles, painted decoration, and even the cross-sectional dimensions of timber members. In the Qing dynasty, for example, the dimensions of official and large-scale buildings were divided into eleven

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[53] The Yingzao Fashi ('Treatise on Architectural Methods or State Building Standards') is a technical treatise on architecture and craftsmanship written by the ancient Chinese author Li Jie, the Directorate of Buildings and Construction during the mid Song Dynasty of China.

[54] the Gongcheng Zuofa issued by the Ministry of Works in the twelfth year of the Yongzheng reign (1734). The document comprises 2,768 pages. Together with the Yingzao Fashi, it represents one of the only two official building manuals promulgated by the imperial state in pre-modern China to standardize architectural construction.

graded levels, ranging from 6 cun to 1 cun, with increments of half a cun (approximately 3.2 cm per cun). Such grading systems linked architectural form directly to institutional rank.

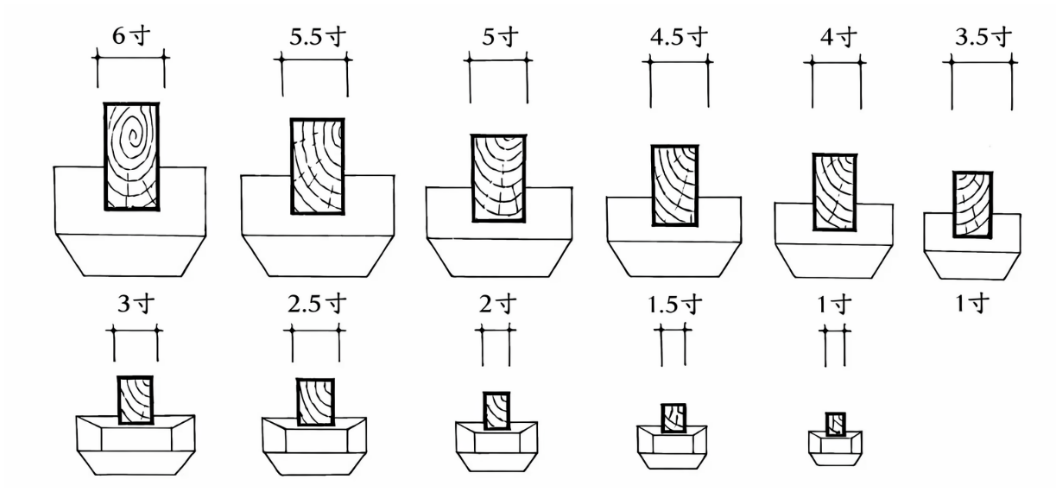

Figure 4.21: Component dimensions were graded according to the traditional unit cun, equivalent to about 3.2 cm in the modern metric system.

Based on the module, proportional rules further defined the relationships between structural components and spatial elements. Through fixed ratios, integer values, and multiples, parameters such as column diameter and height, bay width and depth, frame spacing, vertical rise, and roof curvature were integrated into a coherent and interdependent system. Each dynasty adopted its own proportional rules, reflecting differences in institutional order and construction culture. For this reason, architectural modules and proportions have become important evidence for the reconstruction and interpretation of historical buildings today.

This also suggests that, in the conservation of Chinese timber architecture, attention should not be limited to structural performance alone. The proportional order embedded in traditional construction practice must also be regarded as a key aspect of architectural authenticity.

Chapter 5 Structural Characteristics and Node Details of Timber Systems in Italy

Quelle: Deutsche Fotothek

Figure 5.1: Copperplate engraving from Architectura Civilis (1668), depicting the construction of stone walls, timber members, and a trussed roof system.

5.1 General study of The Traditional Italian Timber System

Western traditional architecture commonly employs enclosing walls as the primary load-bearing elements, as Goethe observed: ‘Our houses do not arise out of four columns in four corners; but from four walls and four sides, which are there instead of all columns, exclude all columns, and where men stick them on, they are a burdening superfluity.’[55] This embodies a construction philosophy where ‘enclosure is structure.’ Within this system, timber, though not the primary structural element, frequently occupies critical positions at the boundaries of construction. As Nicola Macchioni and Massimo Mannucci note in their research:‘Floors and roofs in historic buildings still retain significant timber structures, a feature not commonly found worldwide.’[56]

Wood, with its lightweight, high-strength, and adaptable properties, continues to play a pivotal role across multiple applications—floors, ceilings, staircases, roofs, formwork, and scaffolding—forming a structural system that runs parallel to masonry systems.[57]

Within the entire building system, the timber roof structure is undoubtedly the most complex, most characteristic, and most frequently modified component of European timber construction. In the earliest Greek and Roman traditions, roof structures were primarily based on timber frameworks. Load-bearing systems were formed through the combined action of principal members—such as purlins and ridge beams—and secondary elements including rafters and battens. As spans increased, intermediate support was often introduced through a *post-and-lintel* system to assist the ridge beam. In addition, climatic conditions favored the widespread adoption of pitched

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[55] Johann Wolfgang von Goethe, quoted in Daniel F. Hellmuth, *Johann Wolfgang von Goethe: Architecture as Nature and Symbol* (master’s thesis, Washington University, 1986), 50.
[56] Nicola Macchioni and Massimo Mannucci, “The Assessment of Italian Trusses: Survey Methodology and Typical Pathologies,” *International Journal of Architectural Heritage* 12, no. 4 (2018): 533–544, https://doi.org/10.1080/15583058.2018.1442516.
[57] Roger B. Ulrich, *Roman Woodworking* (New Haven and London: Yale University Press, 2007), 1.

roofs as the predominant architectural form.[58]

Despite the cultural shift towards stone over timber in late Greece, the Romans did not entirely abandon wooden structures. Instead, they developed a distinctive logic for timber usage through both inheritance and innovation. The construction of large public spaces led to truss roofs becoming the most representative timber structural system in Italian historical architecture.

For instance, the span limitations of Greek-period framed roofs and the post and lintel roof (also termed the ‘prop-and-lintel’ roof or ‘trabeated system’) (Figure 5.2) spurred the development of the truss roof (‘Capriata’).

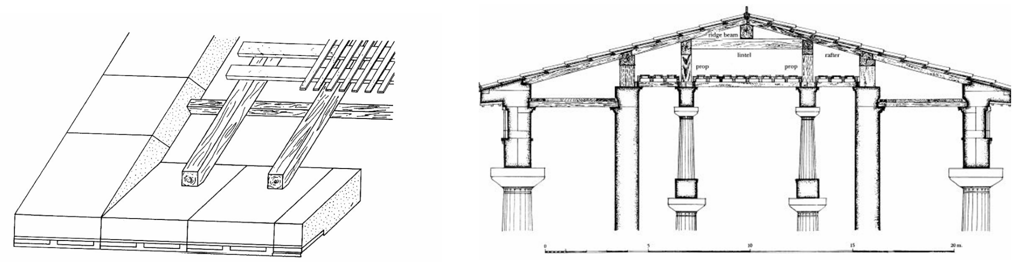


Figure 5.2: Greek roof framing (left) and post-and-lintel roof structure (right).

In addition to timber roof systems, ceilings and floors also represent essential structural components in Italian architecture. Timber floors are particularly common in northern Italy, where builders often adopted raised constructions to create ventilated cavities, thereby reducing the effects of moisture on wooden elements.

Floor and ceiling systems (Figure 5.3) are typically supported by masonry walls, with a timber beam framework forming the primary structural skeleton. Above this framework, layers of mortar and paving materials are added to create the walking surface. Correspondingly, the underside is finished with thin wooden boards, reeds, and

[58] Bingqi Liu, *Comparison of Traditional Italian and Chinese Timber Roofs* (master’s thesis, Politecnico di Torino, 2022), 7.

plaster, forming the ceiling surface, which may also perform a decorative function.

When spans increase, the system usually introduces one or more primary beams to reduce the effective span of the joists, resulting in a two-level load-bearing mechanism defined by a "primary beam–joist" structural hierarchy.[59]

Figure 5.3: Ceiling of a ruined farm at Pompeii, showing the same structure as ancient ceilings: the beams support a parquet on which a layer of mortar is placed.

In the detailing of façades and interior decoration, timber was also extensively employed for door and window frames, balcony cantilever beams, and spiral staircases. For example, staircases in the Roman period were predominantly timber-framed, though they frequently featured a short stone or brick plinth at the base (Figure 5.4).[60] These components were often embedded within stone walls, creating an interface that combined rigidity with flexibility within the main structure.

Figure 5.4: A wooden staircase is located in the plan of the shop at Herculaneum, Insula IV, no. 20., but does not belong to this shop.

[59] Adam, *Roman Building*, 401-410.
[60] Ibid., 410-419.

5.2 Classification and Characteristics of Timber Roofs

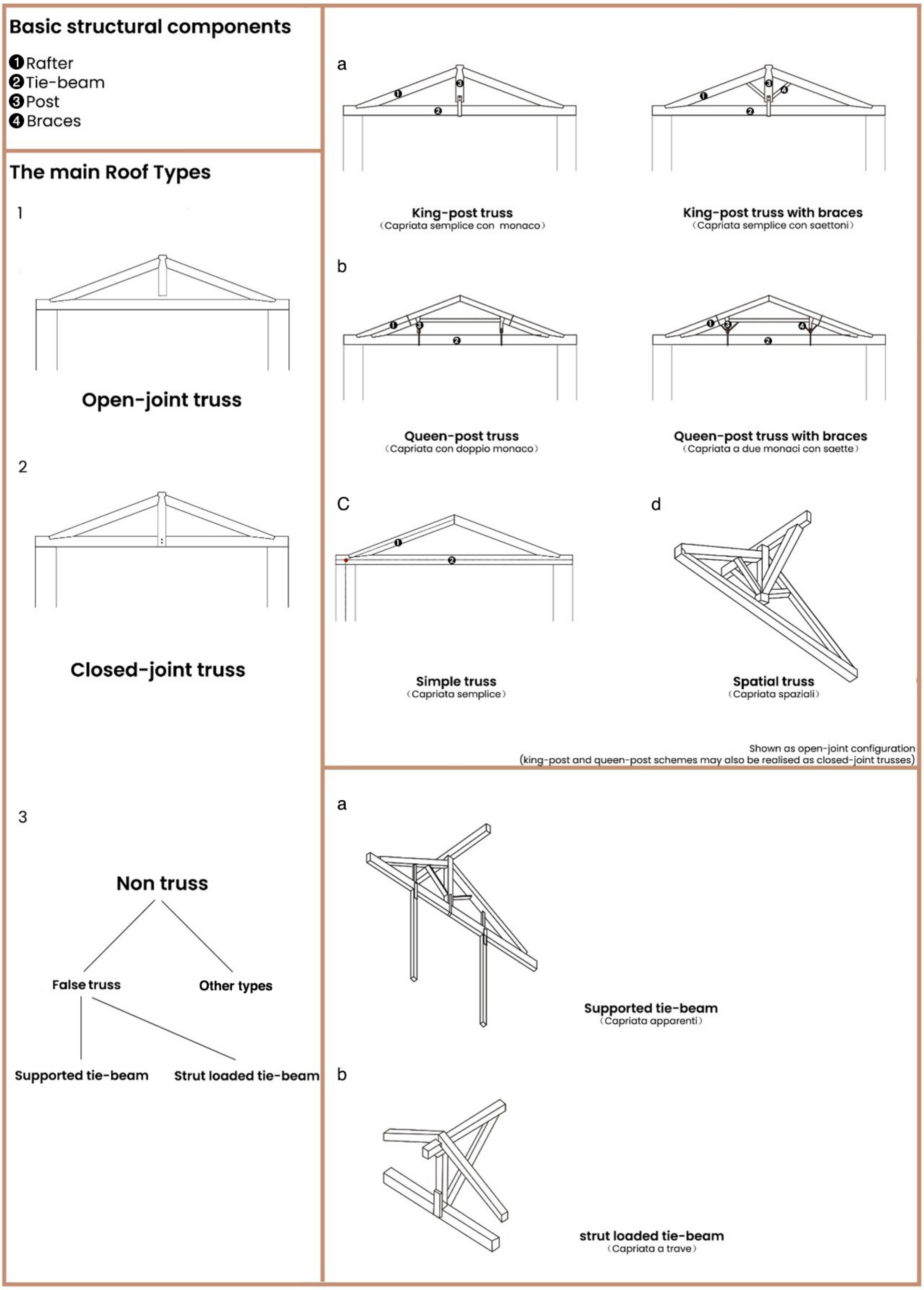


Figure 5.5: Diagram Classifying Roof Types

Unlike traditional Chinese architectural design, which employs a modular system where roof structural components adhere to fixed dimensions and spans based on this modular framework—known as the 'jian'.[61] European architectural tradition don't base on a unified modular system. Roof design in Europe centers on spanning larger internal spaces, giving rise to diverse timber roof structures.

From a structural perspective, traditional Italian timber roofs can be broadly classified into trusses and non-trusses (Figure 5.5).

The wooden truss roof (Capriate Lignee) was mainly employed in churches, medieval halls, monasteries, and other large-span public buildings. Its fundamental components comprise: 1. Tie-beam (catena, under tension); 2. Principal rafter (puntoni, under compression); 3. King post (under tension, pulled upwards by the principal rafters and providing relief). Diagonal braces (saette) may occasionally be added (to prevent sagging of the principal rafters and reinforce the triangular framework) (Figure 5.6).

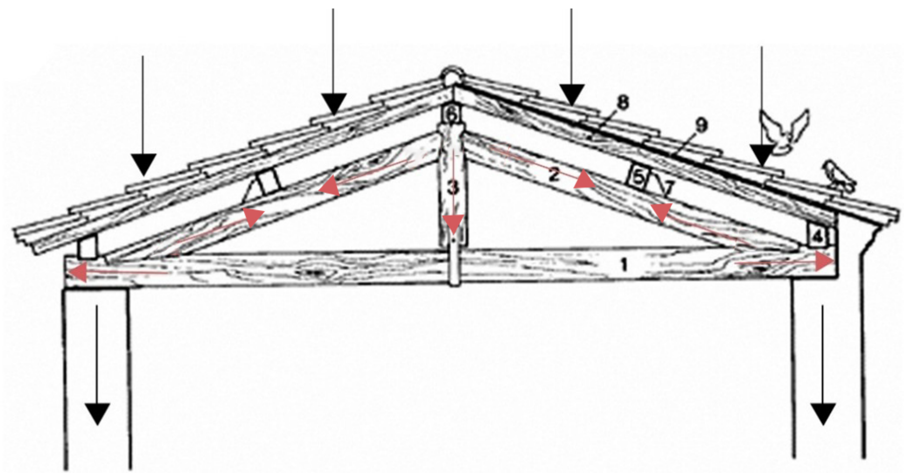


Figure 5.6: Triangulated king-post timber truss. The rafters and the principal rafters work in flexion by transmitting the oblique forces to the tie-beam, which naturally has a tendency to bend, and to the king post, both placed under tension. The various forces are integrated, and the timbers only transmit vertical pressures to the walls.

[61] Bay: Refers to the centre-to-centre distance between two primary load-bearing elements (typically columns). Chinese architecture is not designed to arbitrary dimensions but rather takes the bay as its fundamental unit. The scale and layout of a structure are determined by repeating, adding, or subtracting the number of bays.

Truss structures, through their triangular closed configurations, distribute roof loads evenly to the side walls without requiring central columns, thereby enabling large, unobstructed internal spaces. Unlike the Chinese modular system, Italian roof trusses are bespoken to each architectural space, with components predominantly handcrafted. Connections often rely on interlocking joints, metal fittings, or embedding within masonry, emphasising structural stability.

Trusses are primarily divided into two types: open-joint trusses and closed-joint trusses (Figure 5.5).[62] These systems can be arranged as either two-dimensional or three-dimensional structural configurations and realized through different structural schemes, among which the king-post truss and the queen-post truss are the most widespread.[63] Other types, formally similar to the truss are not-trusses.

5.2.1 Trusses——open-joint trusses

Trusses in which no rigid connection between the posts and the tie beam are commonly referred to as open-joint trusses (Figure 5.7).[64]

Figure 5.7: Detail of an opened joint truss of the roof of a church in Bologna

[62] Macchioni and Mannucci, "Assessment of Italian Trusses," 533.
[63] Umberto Barbisan and Franco Laner, *Capriate e tetti in legno: progetto e recupero. Tipologie, esempi di dimensionamento, particolari costruttivi, criteri e tecnologie per il recupero, manti di copertura* (Milano: FrancoAngeli, 2000),43.
[64] Macchioni and Mannucci, "Assessment of Italian Trusses," 533.

Open-joint trusses are predominantly distributed across northern Italy, accounting for approximately 90% of all trusses. They were particularly employed around 1850, especially in 'conservative' restoration practices.[65] As the central post and tie beams lack physical connection, restraint is achieved solely through metal clamps. In practice, the tie beams do not bear loads from the posts. Only when the tie beams deflect do the clamps begin to pull against the posts bases to compensate. Furthermore, should the ridge be subjected to pressure that risks damaging the tie beams via the posts, restoration may even separate them, thereby maximizing protection for the tie beams and other structural elements.

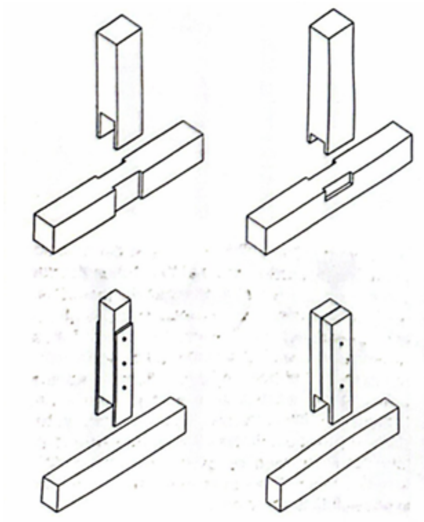
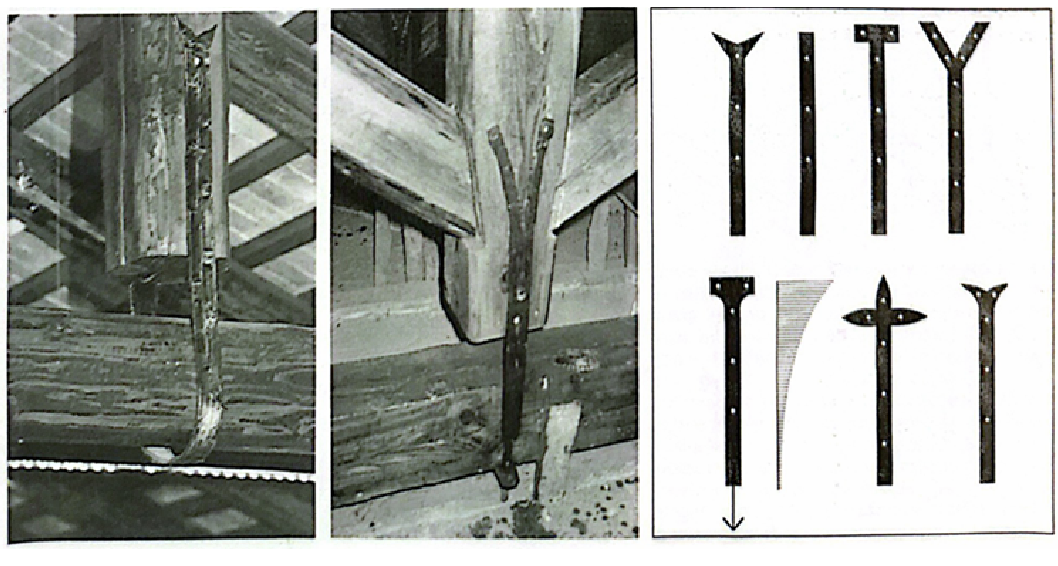


Figure 5.8

Open joint entirely realized in timber (left), characterized by a non-rigid connection between the post and the tie beam, aligned only through shallow seats or wooden pegs; and open joint reinforced by a metal clamp (Below), in which the metal component remains deliberately "loose," engaging structurally only when the tie beam deflects under load, thereby ensuring greater flexibility and durability compared to closed joints.



[65] Franco Laner, *Atlante delle partizioni orizzontali* (IUAV University of Venice, 1997), cited in Umberto Barbisan and Franco Laner, *Capriate e tetti in legno* (Milano: FrancoAngeli, 2000), 40.

5.2.2 Trusses——closed-joint trusses

Trusses in which the king post (or queen post) is rigidly connected to the tie beam are commonly referred to as closed-joint trusses (Figure 5.9).[66]

Figure 5.9 Detail of a closed-joint truss of the Basilica St Paul's Cathedral in Roma.

Closed-joint trusses are predominantly found in regions such as Vicenza and Venice, accounting for 7-8% of all truss types.[67] Unlike open-joint trusses, closed-joint trusses feature rigid connections between the uprights and tie beams, forming closed triangles. While inherently more stable than open-joint trusses, timber rots due to inadequate protection or the roof endures additional stress, the resistance at the joints between rafters and tie beams gradually diminishes. Consequently, the tie beams begin to bear the load of the posts, which further leads to failure occurring at the midpoint of the tie beams where the maximum bending moment is concentrated.

However, closed-joint trusses appeared before 1850, suggesting that open trusses evolved from enclosed ones. The flexible connections and reversibility of open-joint

66 Macchioni and Mannucci, "Assessment of Italian Trusses," 533.
67 Laner, *Atlante delle partizioni orizzontali*, cited in Barbisan and Laner, *Capriate e tetti in legno*, 40.

trusses create safer structures at their joints. Concurrently, as noted in earlier scholarly papers, the prevailing architectural manual of the period, Sebastiano Serlio's Treatise on Architecture published in 1537, provided only truss forms and modular dimensions without detailing joint construction or material selection, its diagrams still employing closed-joint trusses. Guardigli suggests this primarily stemmed from contemporary construction practices outpacing theoretical texts, with specific construction details often determined by craftsmen's experience.[68]

This reflects a divergence from China's practice of pre-designing modular joints, where Italian timber construction relied more heavily on craftsmen's experience and placed greater emphasis on the structural stability achievable at the time.

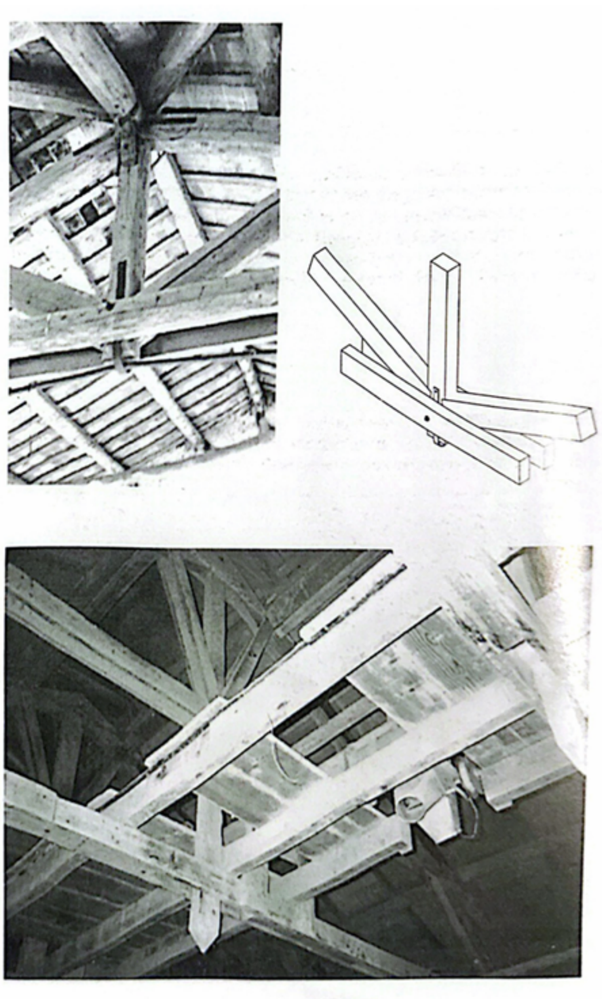


Figure 5.10 Examples of closed-joint trusses in Emilia-Romagna.
Top: Closed joint ("nodo chiuso") with double tie member in a barn at Cà Merloni (Ravenna), illustrating a configuration now commonly used for glued-laminated timber trusses.
Bottom: Hyperstatic timber roof with closed joints in a warehouse at Massalombarda (Ravenna).

[68] Liu, *Comparison of Traditional Italian and Chinese Timber Roofs*, 22

5.2.3 non-Trusses

Italian timber roofs include not only truss structures but also systems that, despite a superficial resemblance to trusses, are structurally distinct, such as multi-layered beams-and-posts systems, which are more appropriately classified as frame structures.

For instance, the roof structure within the tower of Turin's Castello del Valentino is not based on a trussed system, but on a multi-layered beams-and-posts configuration organized as a spatial frame (Figure 5.11).

Figure 5.11. Scheme of a timber frame and its components (left), and inner view of the wooden roof structure of a tower (right).

Structurally, the roof consists of two superimposed portal frames, with the lower frame resting on a massive beam. Structural continuity and stiffness are achieved through diagonal bracing elements extending along the full length of each roof slope and intersecting the pier–beam connections. Additional diagonal members within each frame reduce bending stress in the horizontal beams, while further elements provide direct support to the purlins.[69]

[69] Clara Bertolini-Cestari et al., *Numerical Survey, Analysis and Assessment of Past Interventions on Historical Timber Structures: The Roof of Valentino Castle*, in *Structural Health Assessment of Timber Structures*, eds. Jerzy Jasieńko & Tomasz Nowak (Wroclaw: DWE, 2015), 582.

This configuration demonstrates a structural logic fundamentally different from that of true trusses, despite certain formal similarities.

5.3 Truss Joints, Reversibility, and Structural Identity

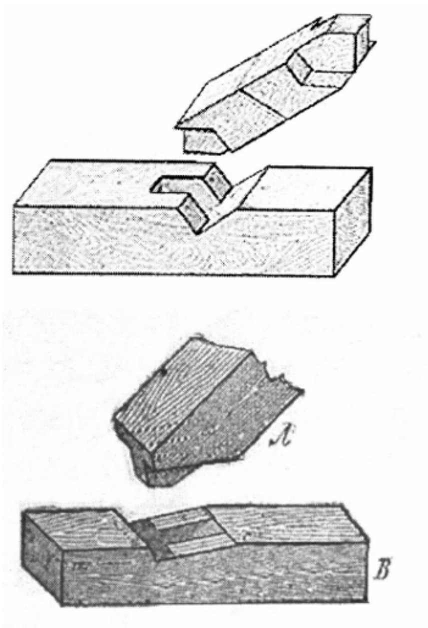
In Italian trussed roofs, joints play a determining role in the overall structural response: they regulate force transfer, constrain or allow relative movements, and strongly influence long-term deterioration patterns. As a result, restoration choices cannot be evaluated solely at the level of individual members, but must be assessed through the joint configurations that define the system's mechanical identity.

Early truss joints were often executed primarily in timber, employing mortise-and-tenon connections and wooden pegs of varying sizes and forms. However, metal fastenings and clamps were already used well before the nineteenth century, particularly where additional confinement, tying action, or local reinforcement were required. With industrialization, and especially with the wider availability of manufactured iron and later steel elements in the nineteenth century, such metal components became more common and standardized, leading to increasingly frequent timber–metal hybrid solutions in both construction and repair.

To clarify these joint characteristics and to provide a consistent framework for the restoration case studies, this section examines three key interfaces: rafters and tie beams, rafters and posts, and trusses and walls.

5.3.1 Rafters (puntoni) and tie-beams (catena)

The junction between the tie-beams and rafters undoubtedly constitutes the most heavily stressed section of the entire truss.[70] In the earliest constructions employing purely timber-to-timber connections, as illustrated in (Figure 5.12), single-tooth, double-tooth, mortise-and-tenon, or hybrid joints were utilized, secured by several nails driven perpendicularly into the teeth. Later, hybrid connections were employed, with the junctions almost invariably fixed using metal U-plates and tension applied by metal wedges. (Figure 5.13)



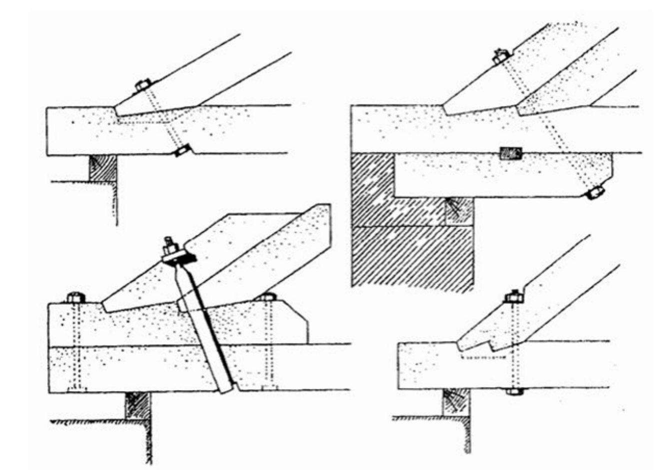


Figure 5.12 Historical illustrations depicting the use of mortise-and-tenon joints, single-tooth joints, double-tooth joints, and nail fastenings between rafters and purlins.

As shown in Figure 5.13, metal plates are frequently employed at the connection points between tie-beams and rafters to secure the assembly. Such metal components have long been employed in traditional Italian truss construction, particularly at critical joints. Metal plates or clamps effectively limit creep, elongation, and progressive loosening of timber subjected to sustained tensile forces, especially where the interlocking action of timber joints gradually diminishes over time.

From the perspective of authenticity, they enhance joint stability and local stiffness while remaining fully dismantlable and reversible, thereby allowing inspection, maintenance, and future intervention.

[70] Barbisan and Laner, *Capriate e tetti in legno*, 97.

Figure 5.13 A tie-beam to rafter joint, showing one connection tooth and two metal plates to maintain in its position the joint. In this case also a short hammerbeam helps in reducing the span of the tie-beam

5.3.2 Rafters (puntoni) and Uprights

Another common connection point is where rafters meet the main uprights. This joint is often secured with nails and appears relatively simple. As shown in Figure 5.14, the head of the main member is intentionally shaped (profiled) to receive the rafters, rather than being irregular. This detail increases the bearing area and provides a more continuous contact surface.[71]

Figure 5.14: The main pillar is carefully shaped (profiled), with each joint being handcrafted to accommodate the upper ends of the rafters.

From a structural perspective, if two rafters were connected directly at the apex

[71] Macchioni and Mannucci, "Assessment of Italian Trusses"

with a sharp corner contact, the load would be transferred through a highly localized region, leading to stress concentration and an increased risk of crushing or splitting at the rafter ends. The shaped interface therefore serves to improve load distribution and reduce local stress peaks at the joint.

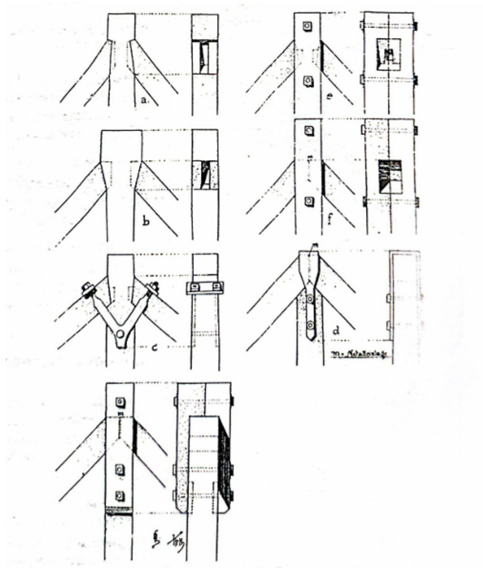


Figure 5.15: Solutions of the *monaco-colmo* and *monaco-puntone* joint.

5.3.3 Trusses and Walls

In early historical practice, the connection between timber trusses and masonry walls was commonly achieved by inserting the rafters and tie beams directly into the wall, often to a depth equal to half or more of the wall thickness. Small masonry units or grouting materials were typically used around the embedded timber ends to stabilise the truss and ensure adequate fixation.[72]

In subsequent developments,, tie-beams were also frequently connected to masonry walls by means of metal strips nailed to the side of the beam and anchored externally (Figure 5.16).[73] This detail improves the restraint at the timber–masonry interface, helping to prevent sliding or loss of bearing and contributing to the overall

[72] Fabio Solarino, Daniel V. Oliveira, and Linda Giresini, "Wall-to-horizontal diaphragm connections in historical buildings: A state-of-the-art review," *Engineering Structures* 199 (2019): 6-11.
[73] Ibid., 9.

stability of the roof–wall system.

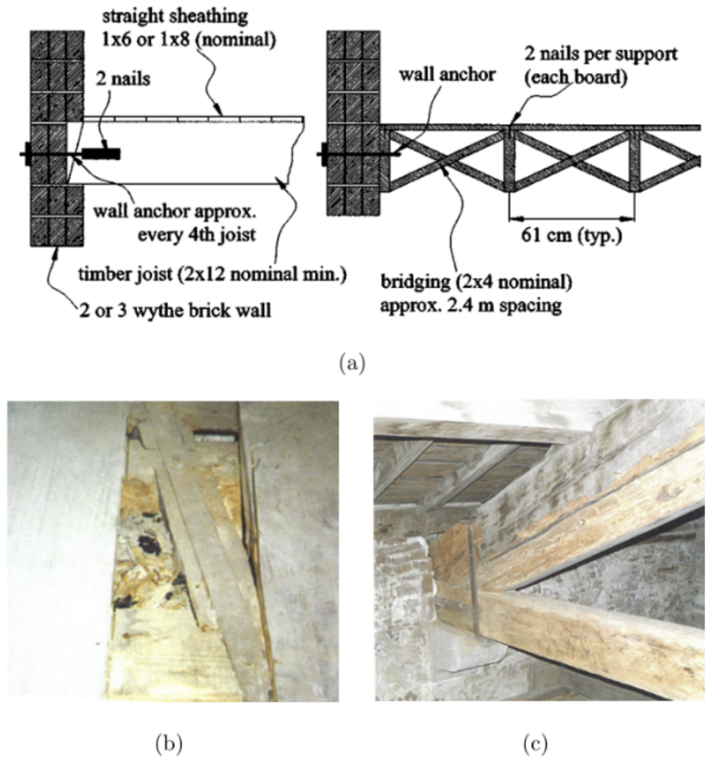


Figure 5.16: Metal anchorages between timber beams and masonry wall: (a) connections between the parallel or perpendicular joist and the wall; (b) diagonal bar embedded into the transversal joists; (c) roof-to-wall connection

However, since the twentieth century, to address beam end decay and ensure the durability of roof timber, practices have gradually developed to improve the interface between roof trusses and walls through ventilation, deflection allowance, and elastic underlay. As E. Griffini (1953) noted in his work:

To ensure the durability of roof timber, wooden components should not be completely enclosed within masonry, lest rapid material degradation occurs, leading to weakening or failure of the timber elements. Particular attention must be paid to the ends of truss tie beams, rafters, and purlins, which rest upon masonry and require especially careful technical measures. These ends should contact dry-laid stone or brickwork, allowing air to circulate freely around them.[74]

The core issue with trusses and walls is preventing rot at beam ends due to

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[74] Barbisan and Laner, *Capriate e tetti in legno*, 94.

moisture entrapment. Consequently, construction designs often employ dry-laid recesses, ventilation cavities, and damp-proofing structures to maintain timber in a dry, ventilated state. Simultaneously, the chain (lower chord) or truss lower chord ends are frequently placed upon stone sills, brick recesses, or banchina joists. This facilitates air circulation around the beam ends, preventing corrosion and biological deterioration caused by capillary moisture rise (Figure 5.17).

These practices do not compromise the wall's static continuity. Instead, by isolating the timber from moisture sources, they enhance the structure's overall durability. Modern restoration projects further incorporate corrugated bricks, damp-proof layers, and metal-assisted joints. This demonstrates Italian restoration's emphasis on structural logic and stability, employing new materials to ensure longer-term preservation. This approach to repairing new materials represents, to a degree, a building culture that balances structural rationality with material protection. While not perpetuating the original materials, the new structural joints guarantee the stability and extended service life of the entire timber structure, ultimately achieving authenticity in conservation.

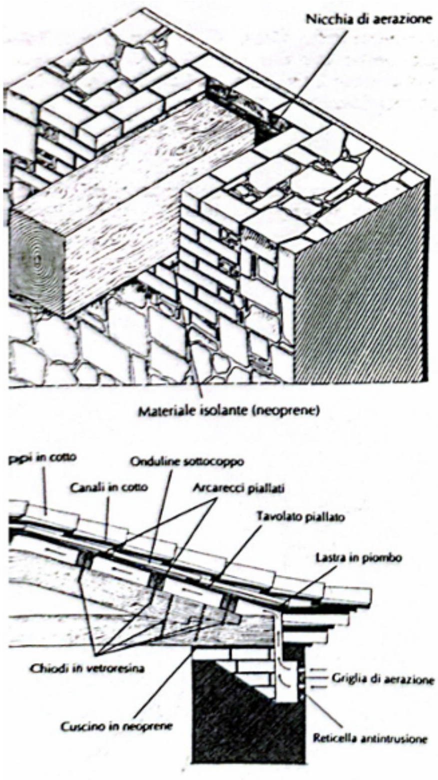

Figure 5.17 Ventilated bearing detail at the timber–masonry interface.

Top: ventilated wall niche (*nicchia di aerazione*) and timber-end embedding with insulating neoprene layer;

Bottom: eave assembly showing brick channels, fiberglass nails, neoprene cushion, piallated boards, and anti-intrusion mesh.

Conclusion

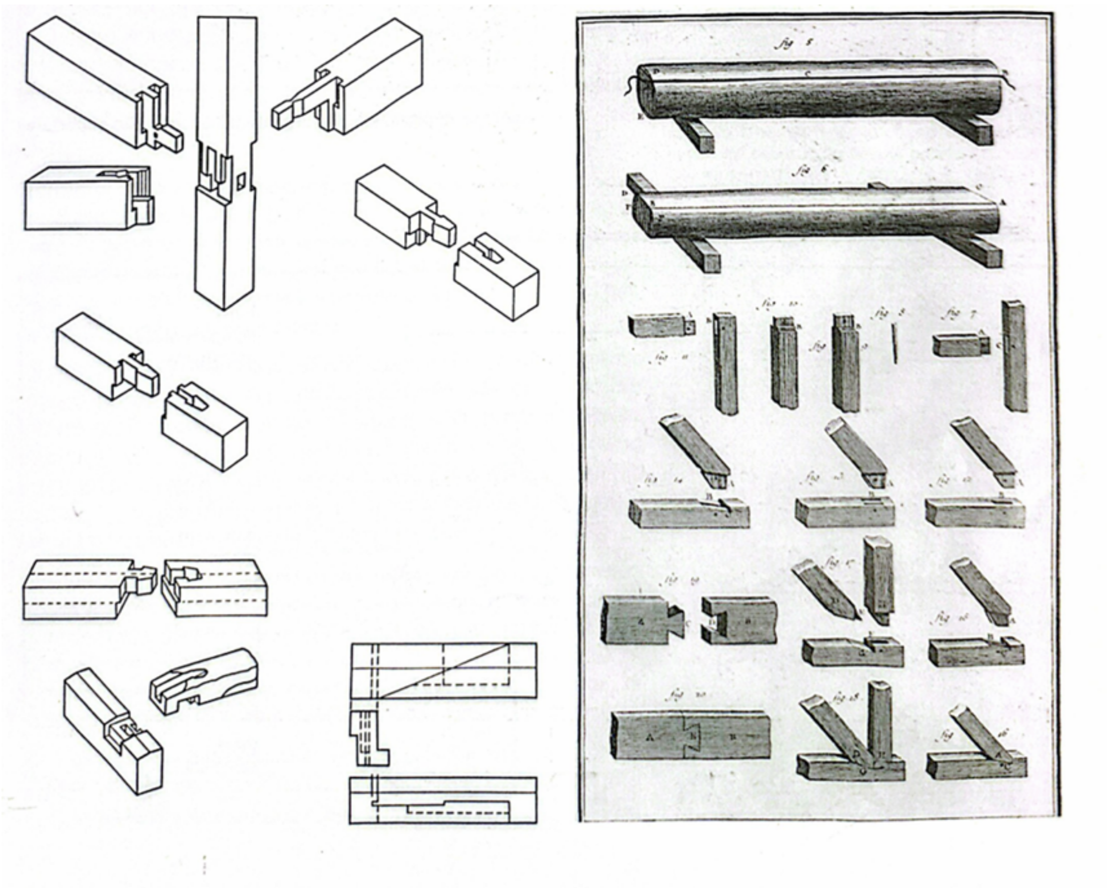

Figure 5.18: Joining and Assembly Methods for Timber Components in Western and Eastern Traditions.

From a structural perspective, this chapter ultimately reveals that the Chinese and Italian systems do not reflect universal differences in “style” but rather demonstrate distinct requirements for joint structural performance. In traditional Chinese practice (Figure 5.18 left), joints are designed as effectively fixed connections. Through the geometry of the timber and enlarged contact surfaces, they resist not only compressive and shear forces, but also, when required, tensile forces via interlocking and friction mechanisms. In many European timber-framed structures and trusses (Figure 5.18 right), joints are primarily engineered to bear compressive and shear forces; tensile resistance is typically provided by metal components—such as tie rods, buckles, or clamps—rather than relying on the timber joints themselves.

However, architectural structural systems are not merely expressions of engineering logic. In timber architecture, constructional methods themselves embody a specific cultural ethic, which in turn shapes distinct conceptions of authenticity. The load-bearing mechanisms and organization of joints determine mechanical stability, while simultaneously reflecting different cultural understandings of continuity, repair, and authenticity.

An analysis of traditional timber roof structures in China and Italy shows that, despite significant differences in construction logic and load-transfer paths, both systems display a certain degree of potential dissolvability and component replaceability at a formal level. Chinese timber frameworks rely on mortise-and-tenon joints, which allow structures to be dismantled and reassembled at the constructional level. Similarly, Italian timber truss systems employ mortise-and-tenon joints or metal-reinforced connections, forming an assemblage-based logic that theoretically permits the replacement of beams, columns, and other structural members. In both systems, this "replaceability" constitutes a structural precondition for adaptability and repair flexibility.

However, from the standpoint of practical conservation, component replacement cannot be regarded as a routine, low-risk intervention. Its feasibility is strictly constrained by the position of each element within the overall load-bearing system, the load-transfer path, and the geometric stability of the structure. At this level, replaceability becomes a critical challenge for authenticity assessment: in the conservation of timber structures, what should be preserved in order to constitute a respectful approach to authenticity?

In the author's view, both Chinese and Italian approaches to timber conservation ultimately aim to express forms of structural authenticity, albeit through different cultural frameworks. In the Chinese context, conservation places greater emphasis on the continuity of constructional craft and building order, rather than on the preservation of original material alone. Authenticity is thus associated with the persistence of joint typologies (mortise-and-tenon forms and assembly sequences), modular systems (such as caifen and doukou), and spatial and ritual principles (including axiality, hierarchy, and proportion). In this sense, authenticity is primarily embedded in the continuity of craft–order systems rather than in the survival of individual components. By contrast, Italy, as one of the principal contexts for the development of modern conservation theory, approaches timber restoration through the principle of minimal intervention, relying on structural and static analysis to maintain the stability and legibility of the original structural system. As noted by Carbonara, “restoration should respect the original structural logic while preserving as much of the original material and form as possible.”

Although Chinese and Italian traditions differ in cultural background and construction logic, their conservation approaches are not inherently contradictory. Instead, they represent two parallel cultural trajectories that illustrate the dynamic nature of authenticity. As discussed in the theoretical framework of Part I, reconstruction played a dominant role in traditional Chinese conservation practice, particularly prior to the modern period. At the same time, Italian architecture has also faced reconstruction in response to destruction caused by war, fire, or earthquakes. In contexts requiring reconstruction or extensive renewal, the Chinese emphasis on craft continuity offers an alternative interpretative framework for the realization of timber authenticity.

From this perspective, reconstruction does not necessarily imply a loss of authenticity, a notion that can also be observed—by analogy—in recent debates on timber roof reconstruction, such as the case of Notre-Dame Cathedral in Paris. Although the new roof employs more fire-resistant materials, it preserves the historic spatial configuration and structural form of the cathedral. From this perspective, reconstruction does not necessarily imply a loss of authenticity but may instead represent one possible mode of its realization in timber architecture.

At the same time, timber structures undergoing routine maintenance and gradual repair must also confront questions concerning the appropriate degree of intervention. Italian conservation practice often relies on detailed static analysis and node-by-node assessment, allowing for limited component replacement or localized reinforcement when necessary to ensure structural safety and overall stability. This approach—aimed at preserving structural integrity while minimizing alteration to original material and form—constitutes another effective means of achieving authenticity in timber conservation. The analysis of joint configurations and load-bearing behavior presented in this chapter provides the technical foundation for implementing such minimal-intervention strategies.

Therefore, the discussion of Chinese and Italian timber structural systems in this chapter does not seek to emphasize differences for their own sake. Rather, by analyzing structural systems, joint mechanics, and potential damage patterns, it highlights the specific challenges of timber conservation and clarifies the boundaries of feasible intervention as defined by structural logic. This structural analysis establishes the basis for the subsequent case studies, in which specific conservation strategies and authenticity assessments are further examined

Part III: Comparative Case Studies—Structural Diagnosis and Intervention Logic in Italy and China

This chapter examines four representative case studies related to the conservation of timber roof structures. Two cases are from Italy, and two are from China. The analysis focuses on three aspects: the process of structural diagnosis of timber roof systems, the rationale behind the formulation of intervention strategies, and the ways in which these technical choices respond to authenticity within specific contexts.

At the level of normative frameworks, the first part of this thesis has reviewed policies, charters, and principle-based documents concerning the conservation of historic buildings and structural intervention in Italy and China, as well as in broader European and Asian contexts. It should be noted that existing regulatory systems mainly provide value-oriented guidance and general principles. They rarely offer directly applicable or unified technical solutions for the repair and strengthening of timber structures. Even when scholars such as Maria A. Parisi have attempted to synthesize principles, standards, and case studies, their contribution lies primarily in providing an interpretive and evaluative framework.[75] Such frameworks cannot replace conservation decisions based on specific structural systems and historical evidence.

For this reason, the adoption of case study analysis in this research is not intended to derive universal technical solutions, nor to evaluate the relative merits of national practices. Rather, through restoration projects that can be clearly reconstructed, this study investigates how different countries implement authenticity through their conservation choices for timber structures.

All cases are examined using a unified analytical framework. However, slightly

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[75] Maria A. Parisi and Maurizio Piazza. "Restoration and Strengthening of Timber Structures: Principles, Criteria, and Examples." *Practice Periodical on Structural Design and Construction* 12, no. 4 (2007): 177–188.

different selection criteria are applied to the Italian and Chinese examples. The Italian cases emphasize differences in structural typologies and joint configurations, allowing an examination of how authenticity is translated into technical practice across different structural systems.

By contrast, traditional Chinese timber architecture is characterized by a high degree of systematization and continuity in its technical lineage. From the Tang to the Qing dynasty, large-scale timber buildings exhibit regional and functional variation, but their structural core is generally based on the beam-frame system and relatively stable construction rules.

On this basis, the Chinese cases are not selected to represent structural diversity. Instead, under the premise of the same historical period and the same structural system, representative cases with sufficient documentation are selected to illustrate the main developmental trajectory and strategic orientation of timber conservation practices in China since the modern period.

Chapter 6 Case Studies—Timber-Structure Restoration in Italy

At the level of technical standards, UNI 11138 proposes a procedure intended to support design decision-making for the repair of timber structures. The procedure does not provide specific rules, nor does it define construction details. Instead, the criteria to be followed at each step are meant to support the designer's decision-making in a way that aligns with objective principles. The procedure includes five steps: (1) preliminary assessment of the state of conservation; (2) intervention plan; (3) criteria for controlling the effectiveness of the intervention; (4) methods and techniques for implementing the intervention; and (5) periodic inspection. Its value lies in offering a decision-making process grounded in objective principles, rather than prescribing specific construction solutions.[76]

For this reason, even when conservation teams generally follow similar workflows, the final strengthening solutions can still differ significantly. The fundamental reasons are the differences in problems arising from different structural typologies, and the differing conservation philosophies of the practitioners.

Based on the typological review of Italian timber roof truss systems in Part II, this chapter selects two restoration projects for comparison. They represent two typical intervention approaches. One aims to "correct structural behavior" and uses limited and identifiable added elements to restore the mechanical logic of the existing system. The other emphasizes "structural reading" and the compensation of "missing links." It maintains the integrity and legibility of the structural system through layered, additive, and lightweight interventions. Both cases focus on timber roof structures and are examined using the same analytical framework: the positioning of the case value, the structural system and diagnostic interpretation, the logical breakdown of the

[76] Ibid., 180.

intervention strategy, and critical reflection.

Through these case studies, this chapter focuses on conservation practice for historic timber roof structures in Italy. Under the premise that authenticity is an explicit conservation objective, it discusses how practitioners translate structural diagnosis into intervention strategies. It should be stressed that the selected cases are not intended to represent the overall level of Italian practice. Instead, the chapter examines projects led by two representative figures, Gennaro Tampone and Francesco Doglioni. The aim is to better analyze the diagnostic process, the rationale of intervention strategies, and their relationship with the principle of authenticity, and to provide guidance and reference for timber structure conservation.

6.1 Palazzo Angelini—Ripatransone, Ascoli Piceno

6.1.1 Relevance of the Case

Figure 6.1: Location of Palazzo Angelini within the historic center of Ripatransone

Palazzo Angelini is situated in the historic center of Ripatransone, within the province of Ascoli Piceno in central Italy. Constructed and extended progressively between the 15th and 17th centuries, it ultimately attained its present three-storey scale. This building exemplifies typical local dwellings, featuring a facade of exposed brickwork (mattoni a vista) that preserves traces of masonry techniques and material stratification from different historical periods. Partial later repairs are visible in the upper sections, reflecting the building's history of ongoing maintenance.[77]

Figure 6.2: View of the main façade of the building

The project was led by Gennaro Tampone's team and was carried out in 2002. As a key figure in Italian research on the conservation and restoration of historic timber structures, Tampone argues that intervention should not be reduced to "increasing strength" or "adding stiffness." He also rejects the idea of "locking" traditional joints by means of modern materials and details. Likewise, he does not accept approaches that require partial or complete dismantling of the structure to replace damaged elements.[78]

Instead, he advocates a minimum-intervention approach. Work should be done in situ. It should be preceded by thorough investigation and a diagnosis of structural behavior, with priority given to preserving original members and materials. He further argues that any added measures should be limited to auxiliary and clearly identifiable

[77] Gennaro Tampone, "Palazzo Angelini—Ripatransone, Ascoli Piceno," in Trattato sul Consolidamento, 2nd ed., ed. Laura Bussi, scientific dir. Paolo Rocchi (Rome: Mancosu Editore, 2004), 401.
[78] Gennaro Tampone and Nicola Ruggieri, "State-of-the-Art Technology on Conservation of Ancient Roofs with Timber Structure," Journal of Cultural Heritage 22 (2016): 1019–1027.

devices, intended to restore the mechanical intelligibility and working logic of the historic structure. In Tampone's framework, the true object of restoration is not the "strength of the timber" itself. It is the continuity and capacity for extension of the traditional timber structural system, and the ongoing coherence of its overall construction and joint logic.

Therefore, the selection of Palazzo Angelini (Ripatransone, Ascoli Piceno) is not motivated by the scale of the building or by the complexity of its roof framing. Rather, although the roof relies on a relatively simple timber structural system, it clearly embodies a rich stratification of historical transformations and interventions. More importantly, the restoration approach does not aim at a generalized "strengthening" upgrade, but focuses on essential and indispensable consolidation measures targeting the roof load-bearing system, in order to preserve the continuity and structural role of the original timber framework.

The final conservation outcome clearly demonstrates the restoration position advocated by Gennaro Tampone. By correcting load-path deviations caused by historical additions, the intervention allows the original truss system to regain overall cooperation and continuity of force transmission. In this way, the project presents one specific path for understanding the authenticity of timber structures within the Italian context.

This strategy directly responds to the earlier discussion on timber structural authenticity. Authenticity is not confined to the preservation of material or form. Rather, it lies in the continued effectiveness of the original structural system as a load-bearing system, and in the intelligibility of its mechanical logic over time.

6.1.2 Structural System and Diagnostic Interpretation

Prior to implementing any interventions, the principles of Tampoine were adhered to any reinforcement measures that must first clarify the structure's historical composition, original materials, chronological sequence of components, and history of previous interventions. The team conducted a structural investigation involving meticulous visual inspection of the roof timberwork, partial removal and direct assessment of masonry surrounding the truss ends.

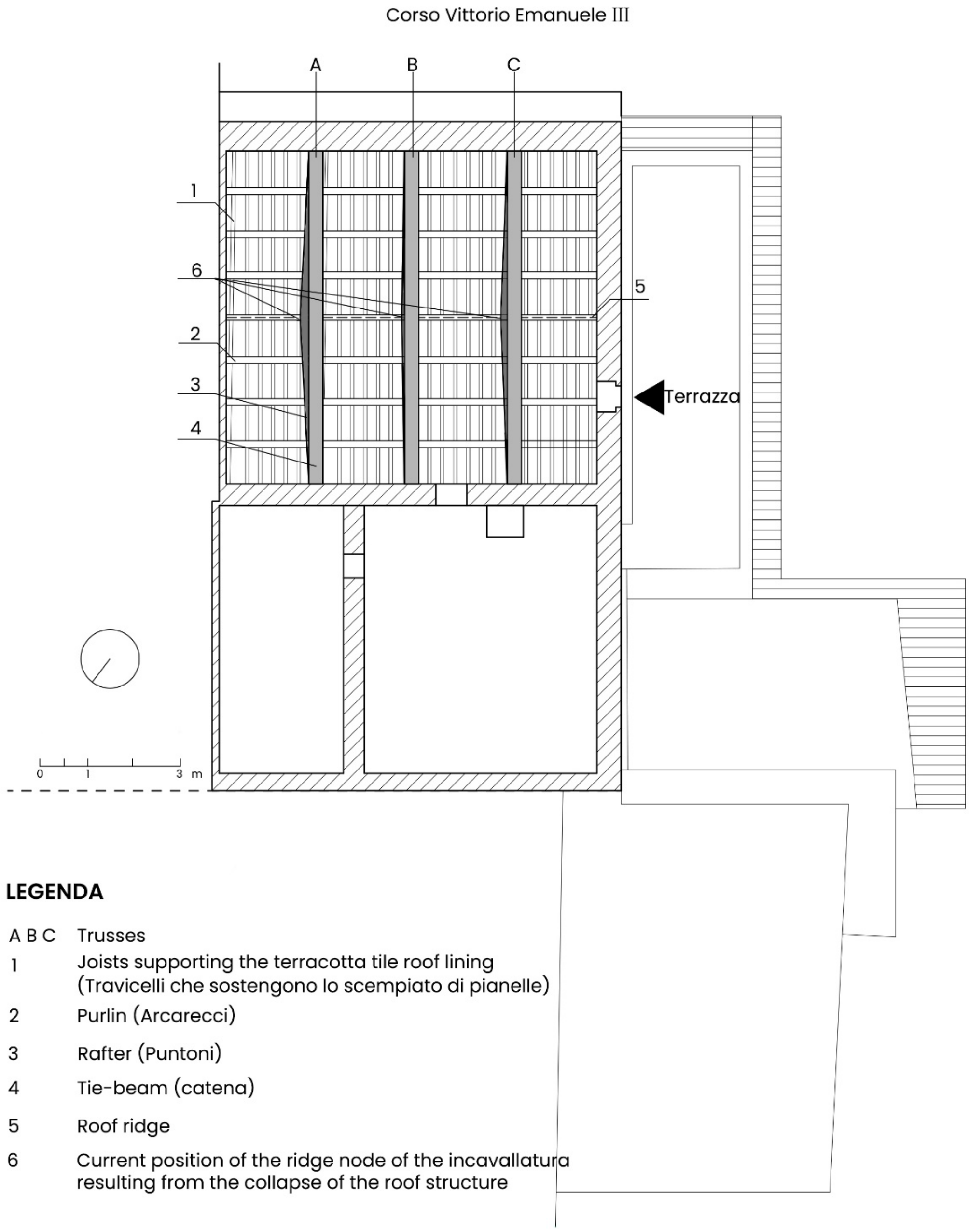

Figure 6.3: Plan of the attic level from below before restoration and indicates the location of the attic on the floor plan

The strengthened roof structure is located above the attic level (piano sottotetto) of the building (Figure 6.3). The timber roof system comprises three simple trusses (incavallature semplici), each spanning approximately 7 meters. Each truss comprises three principal members: a horizontal tie beam (catena) and two inclined rafters (puntoni).[79]

From the plan view, a clear misalignment of the three trusses can be directly observed: they no longer work along the same structural axis. Trusses A and B show the smallest displacement; Truss C, by contrast, presents the most severe displacement.

TIME	Incident	RESULTS
15-17th	constructed and subsequently extended	A three-storey residential building
17th	Intervention (earliest documented date)	Truss strengthening、enclosure of the terrace、roof raising
–	Strengthening of Truss C	Insert a vertical wooden wedge to prevent the rafter from sliding along the tie beam.
		At the ridge position (colmo), an additional structural member has been incorporated, which together with the original member forms a combination resembling a false tie beam(falsa catena) and false rafter (sottopuntone).
		Angle iron connecting the tie beam and rafters
		Install counter-supports near the maximum deflection point of the tie rod; reduce the pressure exerted by this unit on the wall support points.
	Strengthening of wall and Truss C	Install counter-supports near the maximum deflection point of the tie rod; reduce the pressure exerted by this unit on the wall support points.
2022	Gennaro Tampone Team Structural Reinforcement	Structural reinforcement of the framework itself Comprehensive intervention and reinforcement of the roof truss assembly

Figure 6.4: Timeline of transformations and interventions of Palazzo Angelini

79 Tampone, "Palazzo Angelini—Ripatransone, Ascoli Piceno," 403.

The investigation also shows that the roof structure was not built in a single phase but was modified through successive localized interventions and remedial strengthening over time (Figure 6.4).

For instance, truss C had undergone repeated interventions and reinforcement attempts, with numerous iron fittings installed later to 'fortify' the joints. Evidence of corrosion and fiber indentations between these fittings and the original timber is visible, alongside two subsequently added iron tie rods beneath to prevent wall overturning (Figure 6.5). Beneath the trusses, beams of unknown function and a wooden platform framework were found (possibly used for historical roof maintenance) (Fig. 6.6). Some purlins had been replaced multiple times, exhibiting inconsistent arrangement patterns (Fig. 6.7).[80] However, in the current condition, these interventions did not result in a coherent structural strategy and instead introduced additional discontinuities within the structural system.

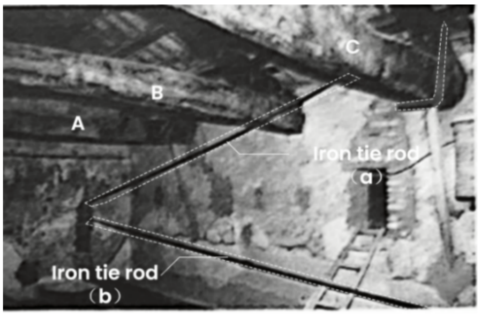

Figure 6.5 Interior of the sub-roof level, viewed from the access, the three timber roof trusses, and the two metal tie rods; note the deflection of the tie beam of truss C in the background.

Figure 6.6 Interior of the sub-roof level, looking towards the access, showing the timber structural system supporting the *cannicciato* vaults of the lower floor.

Figure 6.7 Interior of the sub-roof level, showing details of the timber roof truss system.

[80] Ibid.

Furthermore, the section view shows that the tie-beams of Trusses A and B are slightly cambered upward, with very small curvature. By contrast, the tie-beam of Truss C shows a slight downward deflection (Figure 6.8).

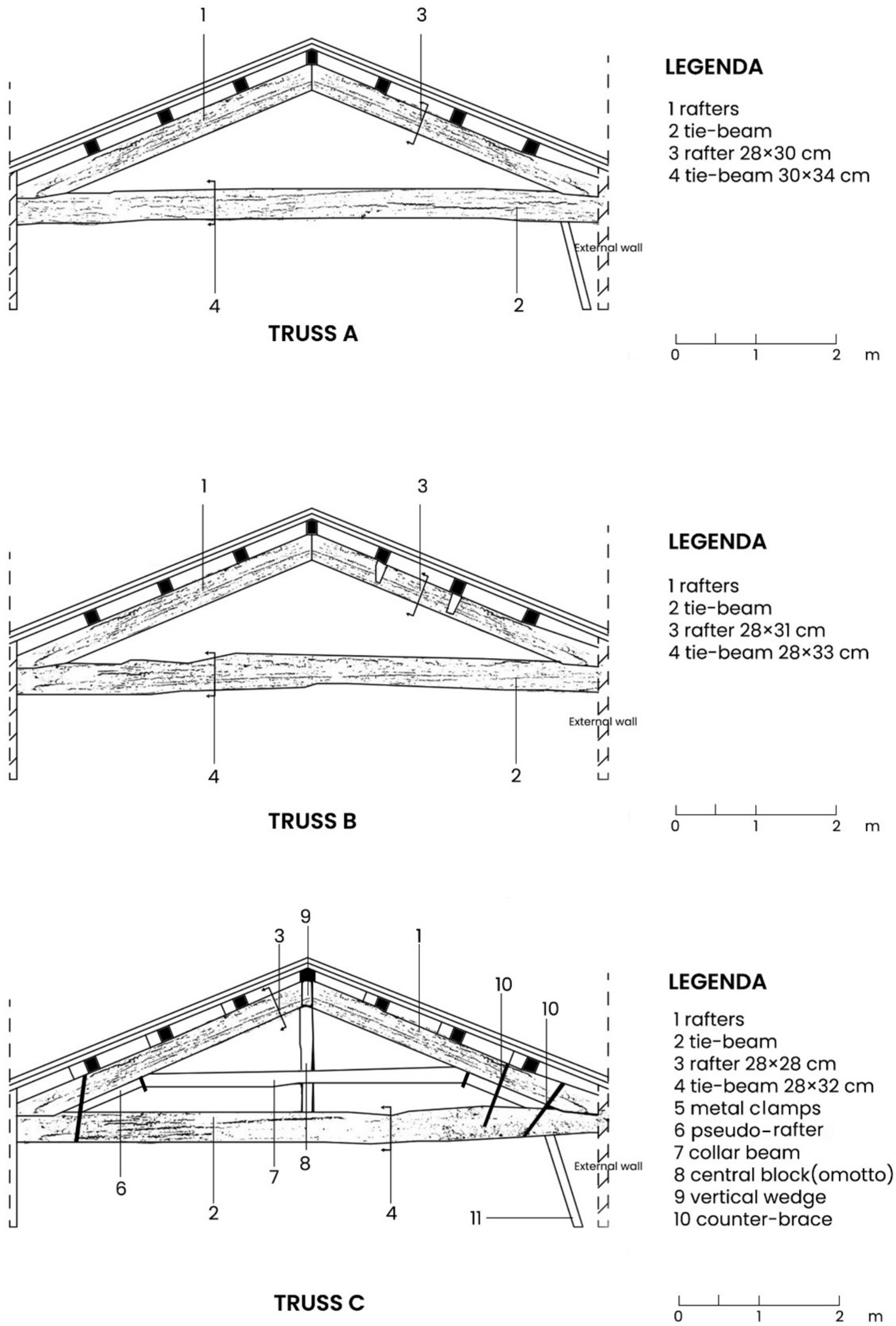

Figure 6.8: Section of the timber roof truss A、B、C

The section (Figure 6.8) also marks the previous strengthening measures and interventions applied to Truss C. For example, at the ridge, several additional members were introduced. These elements form a system comparable to a collar beam and rafters pseudo, connected by iron plates. They create an internal arch-like structure.

A central member was inserted between the original tie-beam and the collar beam, and another between the collar beam and the ridge. At the left node of Truss C, two parallel metal clamps were also installed to connect the tie beam and the rafter, to prevent further opening of the joint angle. To prevent actual rupture of the tie beam in Truss C, the most recent intervention introduced a supporting vertical post (*contrafisso*) at the location of maximum deformation. This element was also intended to reduce the pressure exerted by the truss unit on the wall support.[81]

However, the structural diagnosis ultimately concluded that among all trusses, Truss C concentrates on the key failure mechanisms of the entire roof system. In the current condition of Truss C, pronounced deflection is still observed in the left diagonal strut. At the same time, in all trusses, sliding of the two diagonal struts relative to the tie beam can be observed. These problems indicate, on the one hand, that the timber members were made from irregularly shaped wood and that their cross-sectional dimensions were insufficient to carry the static functions assigned to them. On the other hand, past interventions attempted to introduce a collar beam and rafters' pseudo. This merely demonstrates that the structural problems persisted over time.

From the analysis of the mechanical load paths, the severe deformation of the tie-beam in Truss C and the potential risk of rupture are mainly caused by an incorrect positioning and distortion of the node between the tie-beam and the rafter. Specifically, the node is excessively inward with respect to the supporting wall (Figure 6.8); moreover, the right rafter is significantly deformed and, consequently, the force it

[81] Ibid.,404.

conveys to the tie-beam is mainly transferred close to the rafter's intrados due to the partial contact between the two elements. As a result, the torque generated by the vertical component of this force and the reaction of the masonry wall induces a significant bending moment at the node, with a particularly large lever arm under these conditions.[82]

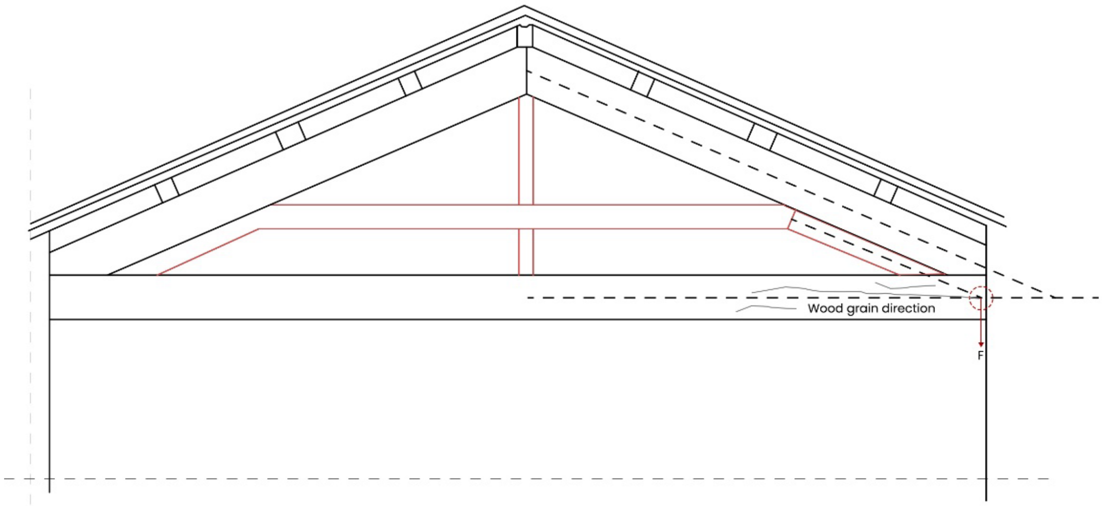

Figure 6.9: Section of the timber roof truss C

Furthermore (Figure 6.9), the strengthening measures that were subsequently introduced—namely, the installation of a collar-beam and two additional rafters—unexpectedly aggravated the structural behavior. The load transmitted by the new rafters acts directly on the tie-beam, increasing both the vertical force component (which acts perpendicular to the timber fibers, i.e. the weakest defection) and the moment's lever arm (with an increase of the bending moment).

Regarding the purlins, uneven boarding layers are observed due to the displacement of the trusses. This indicates that the load-transfer path of the upper roof has been distorted, resulting in reduced load-bearing stability of the roof brick layer (*pianelle*). As for the Joists supporting the terracotta tile roof lining (Travicelli che

[82] Ibid.,405.

sostengono lo scempiato di pianelle), node rotation has caused misalignment. This, in turn, has led to irregular spacing within the beam grid.

Overall, the roof system has lost its ability to work as an integrated whole due to joint slippage (ABC), rafters' deflection (ABC), and sagging tie-beams (most severe at C), and cracking of the masonry walls. Truss C is in a particularly critical state of instability. The failure of the roof system is not caused by the deterioration of a single member. Instead, it is triggered by a systemic imbalance in the relationship between nodes and supports.

Those earlier interventions were not based on systematic reasoning or an integrated design approach. Their execution was also incomplete, and the fundamental structural problems were not properly identified. As a result, the previous strengthening measures were fragmented, temporary in nature, and ineffective.

6.1.3 Logic of the Intervention Strategy

Based on preliminary analysis of the roof structure and historical data, the restoration team regarded the timber roof as a historical construction system characterized by multiple superimposed phases: crude original construction, simple component arrangements, non-standardized jointing methods, and timber of varying quality collectively constitute the building's 'structural stratigraphy'.

These inconsistent construction characteristics, along with the resulting deterioration and deformation, are both causes of structural degradation and integral components of the building's authenticity. Consequently, Tampone's restoration strategy does not pursue 'defect elimination' but rather aims to restore structural safety and usability while preserving these historical traces to the greatest extent possible.

The restoration primarily addressed two major aspects: reinforcement of the trusses itself and overall strengthening intervention of the roof truss system.

Firstly, the reinforcement and restoration of the three trusses are addressed, as illustrated in Figures 6.10 and 6.11. The restoration preserved most serviceable structural elements, employing minimal excision and localized supplementation to maintain the original construction form and material authenticity.[83]

This was achieved by installing metal (cerchiature) to constrain diagonal brace movement at the joints, whilst repairing timber decay or compression damage at the original joints, thereby restoring the normal mechanical path between components.

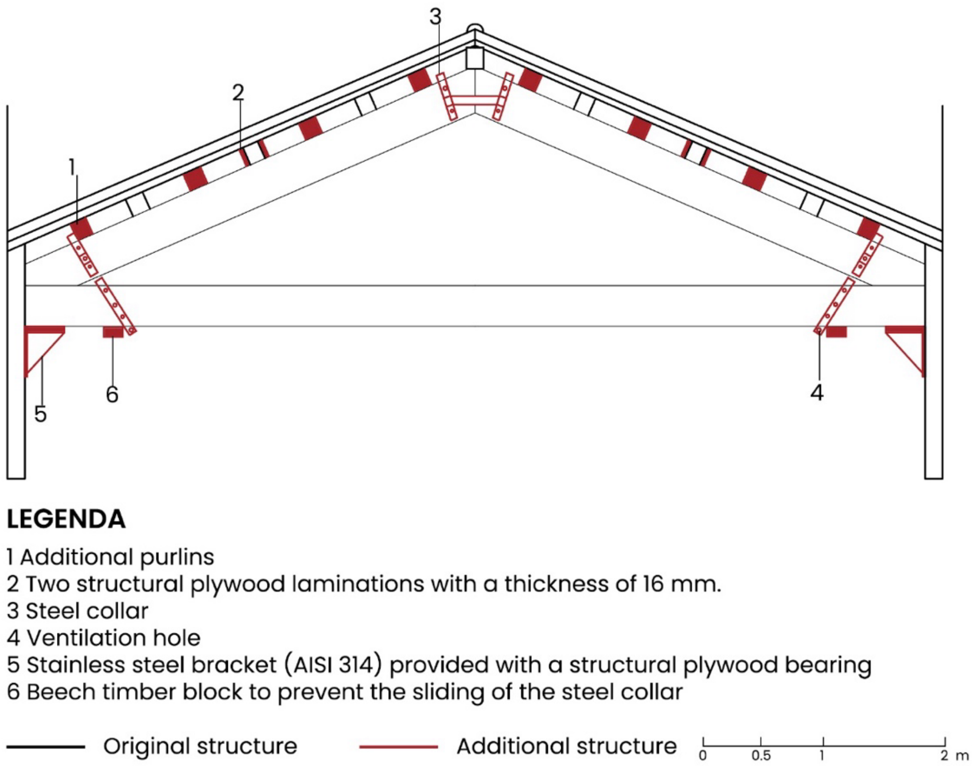

Figure 6.10: Section of the trusses A and B after restoration

For the rafters–tie beam joints (Figures 6.10 and 6.11), the aim was to enhance

[83] Ibid.,405-409.

strength and prevent slippage. Therefore, metal hoops (cerchiature) were introduced to restrain the sliding of the rafters at the joints and to repair the original timber affected by decay or compressive damage, thereby restoring the normal mechanical load path between the members. The steel hoops are provided with ventilation holes to avoid encapsulation-induced decay and to prevent damage to the original timber caused by the new elements. At the same time, timber pads are placed between the collars and the original wood, explicitly defined as sacrificial materials, to facilitate future maintenance.

Among the trusses, Truss C was identified in the previous section as having the most unfavorable structural condition. Nevertheless, the additional timber members introduced during previous interventions were retained in place to preserve the historical stratification, and the current intervention was carried out on this basis. Lateral tie rods were added at both joints to reduce and rebalance the tensile stresses within the timber members (Figures 6.11).

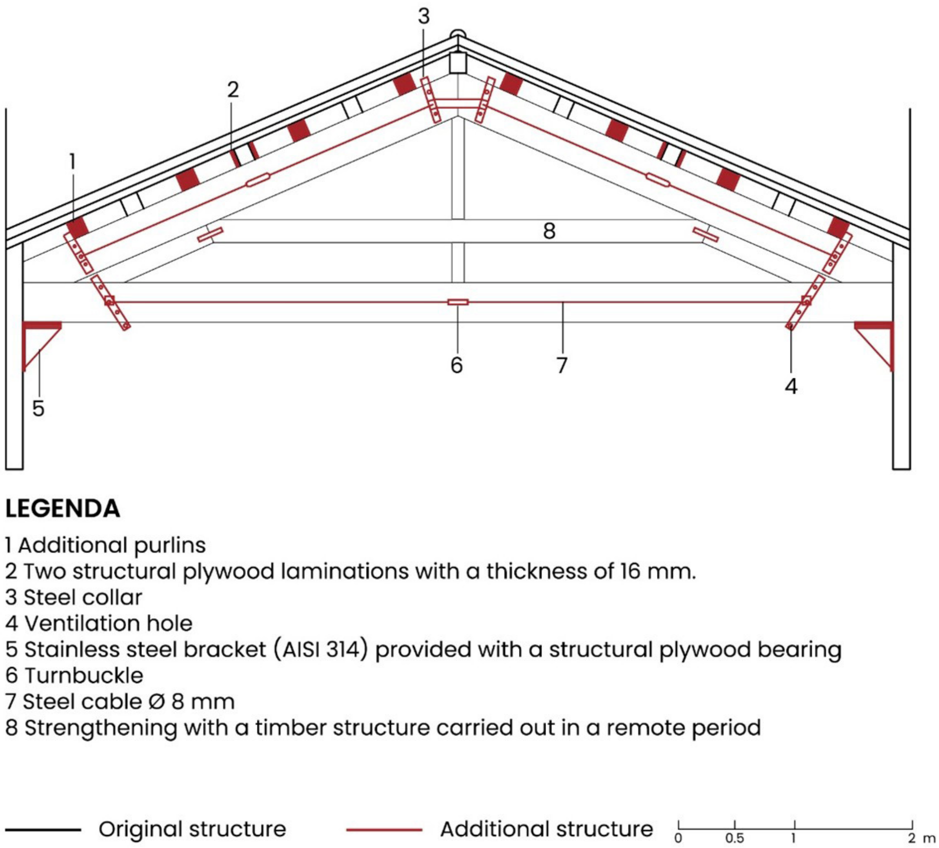

Figure 6.11: Section of the trusses C after restoration

For the purlins, the intervention likewise consists of localized strengthening or replacement. Structural plywood laminations were added onto the original members, and an additional row was introduced, following the logic of the original structural system, to ensure that the roof loads can be evenly distributed (Figure 6.12).

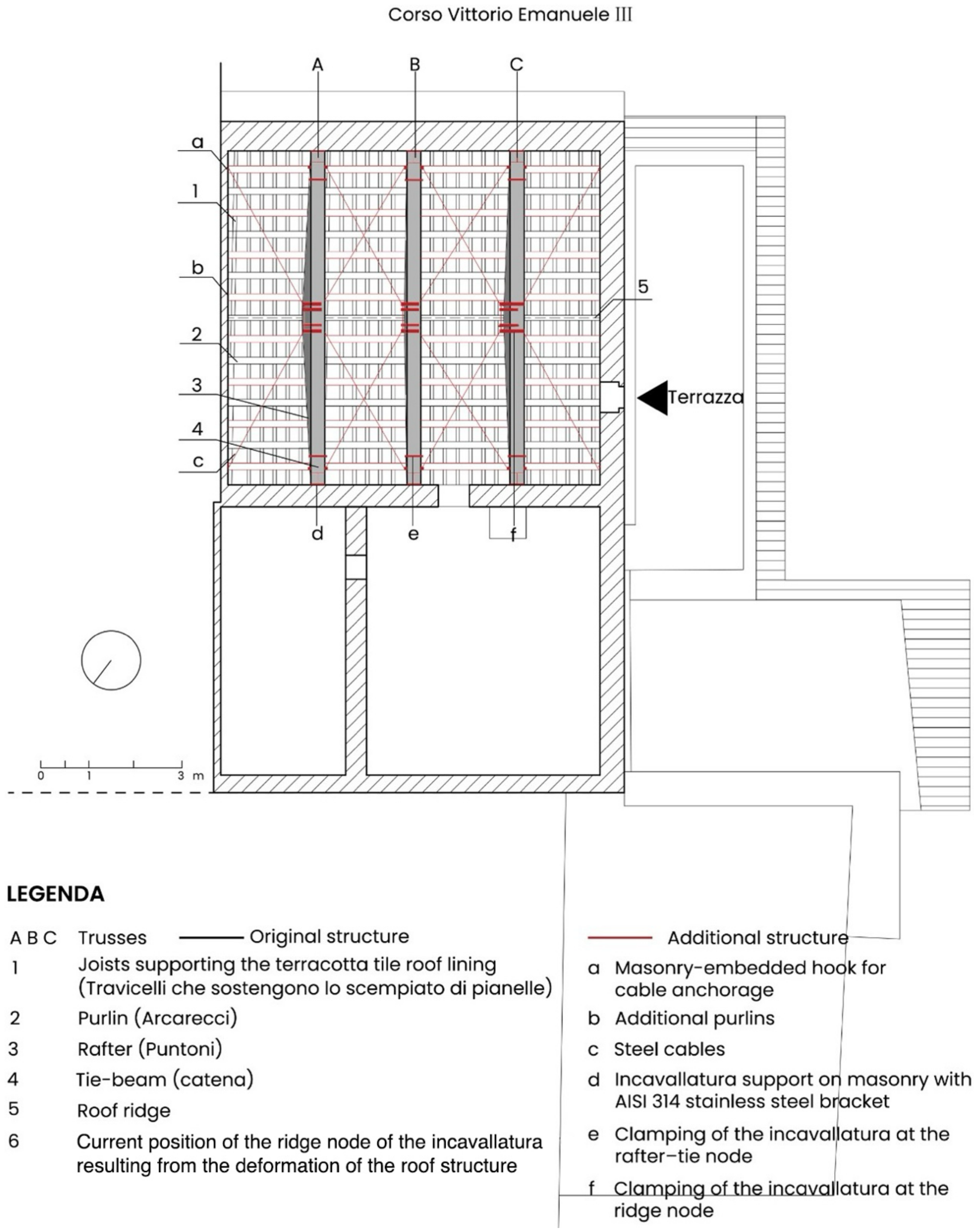

Figure 6.12: Plan of the attic level after restoration

At the truss–wall interfaces, new supports were constructed through a combination of metal elements and plywood pads, allowing the truss ends to obtain stable and controllable reaction conditions and preventing further sliding. For the decayed portions at the embedded ends, the deteriorated material was retained, and hardwood (beech) dowels were bonded to the original members to extend the effective load-bearing zone.

The second aspect concerns the overall reinforcement of the roof trusses. The diagram up (Figure 6.12) shows the roof plan following restoration. A new integrated rigid system (sistema rigido) was established. A steel cable system spanning three trusses was installed, with 8mm diameter steel cables arranged between trusses A, B, and C. Turnbuckles (tenditori) were fitted to precisely regulate force, constraining the three trusses from 'individual deformation' into 'integrated synergy'.

Figure 6.13: Virtual view of the trusses after the consolidation intervention

Figure 6.14: Virtual view of the trusses after the strengthening intervention

6.1.4 Critical Reflection

In summary, regarding material authenticity, the restoration strategy in this case prioritized the maximum preservation of existing timber members. Material continuity and overall integrity were maintained through local repairs, strengthening measures, and reversible interventions, rather than through the reconstruction or wholesale replacement of original elements with new materials. This approach allows the retention of the timber's age-related characteristics, traces of use, and patterns of material degradation, thereby preserving the authenticity of the material as historical evidence. It should be emphasized that what is conserved here is not only the "original material" in a strict sense, but also the temporal stratification and repair traces accumulated through long-term use and maintenance. Although these traces do not necessarily correspond to the building's initial construction phase, they constitute important evidence of the structural system's historical evolution.

Concerning structural authenticity, the focus lies in restoring the original load-bearing logic rather than recreating the structural system. The reinforcement process did not alter the truss type or structural logic. Instead, through joint restoration and force path calibration, the structure continues to function in its original manner. This embodies respect for the principle of 'irreplaceable historical structural logic' in Italian restoration practice. Simultaneously, maintainability is ensured: new components employ externally mounted metal fittings, remain clearly identifiable, and avoid confusion with the original structure, ensuring transparency in the restoration process both visually and technically. This approach aligns with Italy's authenticity principle emphasizing 'legibility'. Newly added elements also maintain reversibility, permitting future removal, replacement, or enhancement.

Crucially, the methodology employed here explicitly embodies the minimal intervention principle (criteria minimalist) championed in Italian heritage conservation:

restoration is confined to what is strictly necessary for structural safety, avoiding unnecessary replacement or reshaping of original components.

Overall, this case exemplifies not the restoration of a "perfect structure", but rather the quintessential Italian approach to conservation: ensuring the continued existence and safe functioning of ancient timber structures with their inherent historical character and imperfections, through minimal, reversible interventions that preserve structural authenticity. This represents the most characteristic Italian technical response to the concept of authenticity.

6.2 Palazzo di Villabruna—Feltre, Belluno

6.2.1 Relevance of the Case

Figure 6.15: Location of Palazzo di Villabruna

Palazzo Villabruna, situated in Feltre, Veneto, Italy, now serves as the Feltre Municipal Museum. Originally a simple "warehouse building" (edificio a fondaco), it underwent a fundamental transformation between the 15th and 16th centuries. Its form evolved into a "more veneto" style palace, characterized by a tripartite layout opening onto the street. Key features include: a central through hall (sala passante), Trifore windows on both sides, and the towering outer gable wall (timpani) facing east.[84]

Figure 6.16: The facade of Palazzo di Villabruna

The project was led by Francesco Doglioni's team and was carried out in 1986. Doglioni stands as one of Italy's most influential scholars and practitioners in contemporary architectural heritage conservation. His longstanding focus encompasses structural pathology analysis in historic buildings, research into traditional timber truss systems, and the practical application of 'structural authenticity (autenticità strutturale)' within heritage preservation. In his thesis on Consolidation,[85] Doglioni addresses the issue of strengthening historic structures, arguing that reinforcement is not synonymous with structural enhancement and should not be regarded as an automatic component of restoration.

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[84] Francesco Doglioni, "Palazzo di Villabruna – Feltre, Belluno," in *Trattato sul consolidamento*, 2nd ed., ed. Laura Bussi (Rome: Mancosu Editore, 2004), 272.
[85] Ibid.,272-275.

The core of structural restoration lies in reinterpreting the construction logic of historic buildings: identifying the “lacuna” within the structural system, understanding its original mode of operation, and restoring its mechanical equilibrium through the most minimal and reversible compensatory measures possible. Thus, the true object of restoration is not the “strength or weakness of materials”, but the “integrity of the structural system”. [86]

The selection of Palazzo di Villabruna (Feltre, Belluno) as a case study does not aim to provide a universal approach to timber restoration, but rather to illustrate Doglioni's restorative philosophy – how to interpret structural issues themselves. This case analysis demonstrates how Doglioni's approach to timber restoration achieves authenticity.

Structurally, the Palazzo di Villabruna roof resembles a Palladian truss system featuring semi-open joints, timber mortise-and-tenon connections supplemented by localized metal plates. Doglioni's reinforcement approach employed layered strengthening techniques, prioritizing the preservation of substantial original structural elements. This restoration selection remains highly representative.

6.2.2 Structural System and Diagnostic Interpretation

The roof adopts a hipped form, primarily supported by three large wooden trusses. These trusses bear a 16-metre-long grid beam (trave reticolare) whose structural configuration approximates the Palladian truss (alla palladiana).[87]

According to the roof geometry, the system comprises two triangular trusses (B and C in Figure 6.17) and one trapezoidal truss (A in Figure 6.17).

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[86] Ibid.,272.
[87] Ibid.

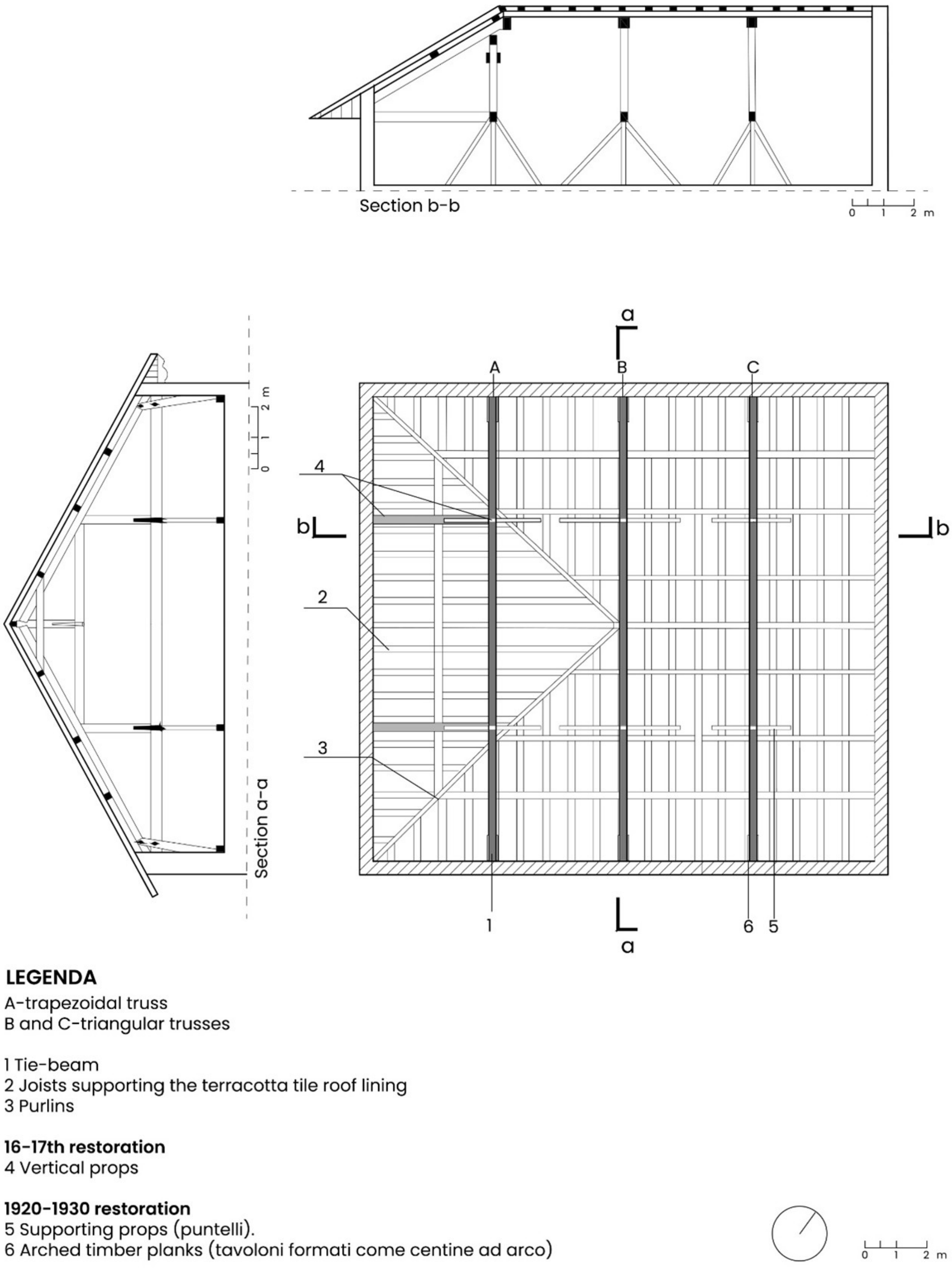


Figure 6.17: Plan and sections of the roof before restoration

Similarly, prior to the implementation of any strengthening measures, the research team clearly identified the configuration of the roof structure, the original construction materials, and the history of previous interventions. Figure 6.18 summarizes the restoration process of Palazzo Villabruna according to its main chronological phases.

TIME	MEASURES	RESULTS
15th–16th	**—Transformation** 1、Warehouse-style buildings transformed into "More Veneto"-style palatial residencesresidence 2、One of the extremely thin gables was constructed not to extend all the way to the roof, but to terminate at the level of the top floor slab.	1、Forming a hybrid construction, its interior filled with discontinuities
16th–17th	**—The roof has been slightly raised** 1、The trusses have been newly constructed or merely relocated 2、Metal clamps were fitted for repairs, and small pillars were added near the trusses to provide additional support. Some were erected on the gable walls, while others were directly supported on the wooden floorboards.	1、Two "monk columns" within the original truss structure sustained excessive vertical loads due to inadequate node construction, resulting in significant deflection and subsequent fracture of the lower chord chain. 2、Maintain the stability and integrity of the drop beam structure, sharing the vertical loads.
1920-1930	**—Temporary reinforcement** Architect and town planner Alberto Alpago Novello 1. Added pairs of curved wooden planks (tavoloni formati come centine ad arco) to both sides of each truss. 2. Added more rationally distributed support struts (puntelli).	1. To redistribute the load to lower support points. 2. To counteract further deflection of the chain (catene)
1986	**—Reinforcement** 1. Full-house inspection 2. Layered / stacked reinforcement	1、Enhancing seismic efficiency. 2、The approach of minimal intervention preserves the original structure.

Figure 6.18: Timeline of transformations and interventions on the roof structure

Based on the investigation, the building's structural system was reconfigured in response to functional changes in the fifteenth–sixteenth centuries. In particular, the roof trusses were constructed—or at least relocated to their current positions—during a limited roof-raising campaign carried out between the fifteenth and sixteenth centuries. As a result, the roof evolved into a hybrid structural assemblage, and this adaptive transformation did not produce a fully coherent, continuous structural system (Figure 6.19).

Figure 6.19: Interior view of the roof space before restoration (1986), showing the deformed timber truss system, temporary propping, and the deteriorated condition of the wall and roof boarding.

Within this structural configuration, two suspended central posts rest on the lower tie beams. The tie beams, composed of timber elements connected by dovetail joints, were required to carry a significant portion of the vertical loads, resulting in pronounced deflection and, in some cases, near failure; one of the tie beams was subsequently repaired using metal straps.

Therefore, before the recent intervention, the three roof trusses had already been subject to earlier strengthening measures, as illustrated in Figure 6.20. During an early phase of intervention in the sixteenth–seventeenth centuries, several vertical props were introduced: some were placed directly over the spine walls, while others bore directly on the timber floors. Subsequently, between 1920 and 1930, the architect and urban planner Alberto Alpago Novello carried out an economical yet effective provisional strengthening campaign, installing paired arched timber planks (tavoloni formati come centine ad arco) on both sides of each truss and adding more evenly distributed supporting props (puntelli).[88]

[88] Ibid.,273

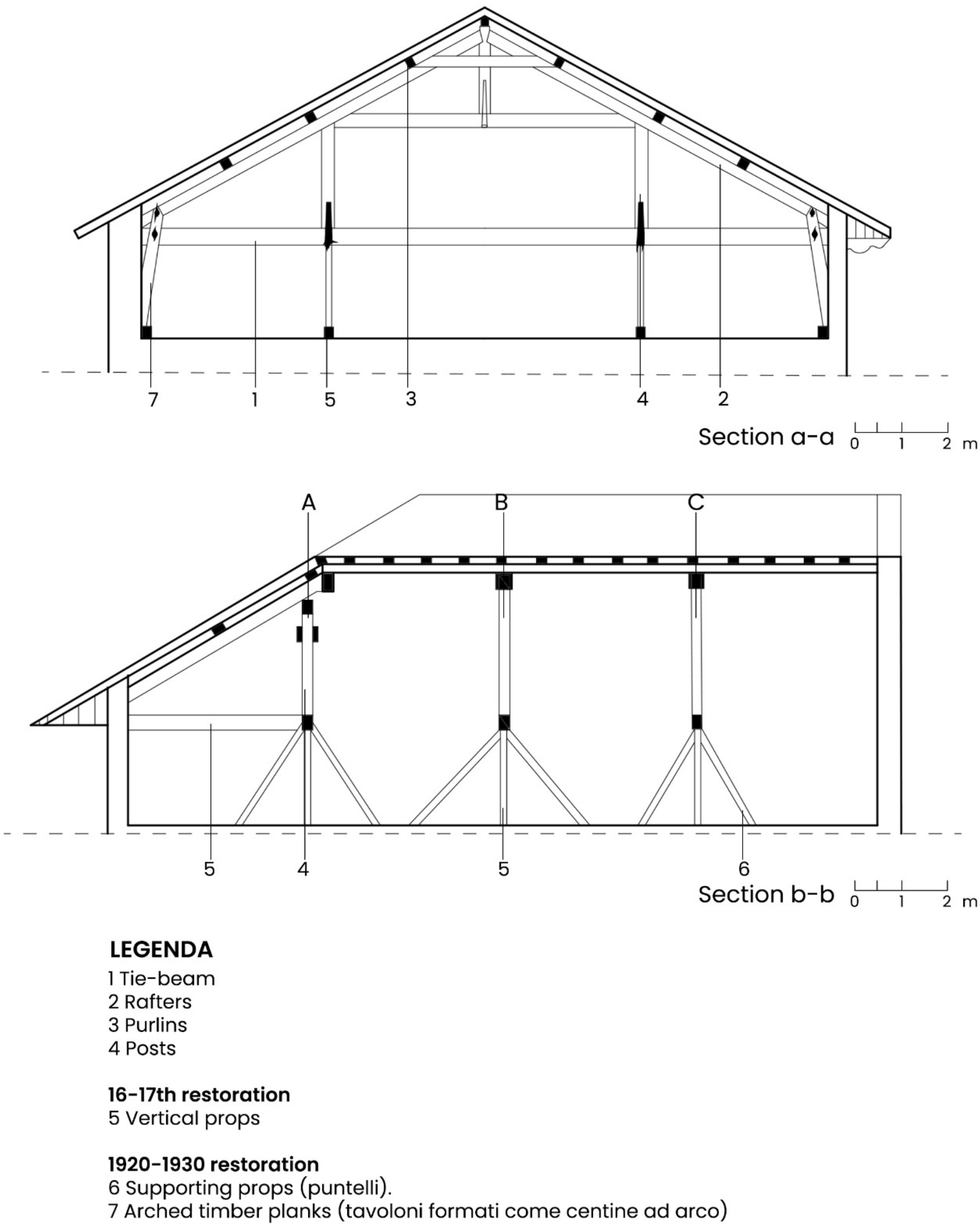


Figure 6.20: Section of the roof before restoration

In 1986, a comprehensive building survey conducted by Doglioni at Palazzo Villabruna identified significant structural problems in the roof system, together with water infiltration from the covering that had caused deterioration of the timber elements.

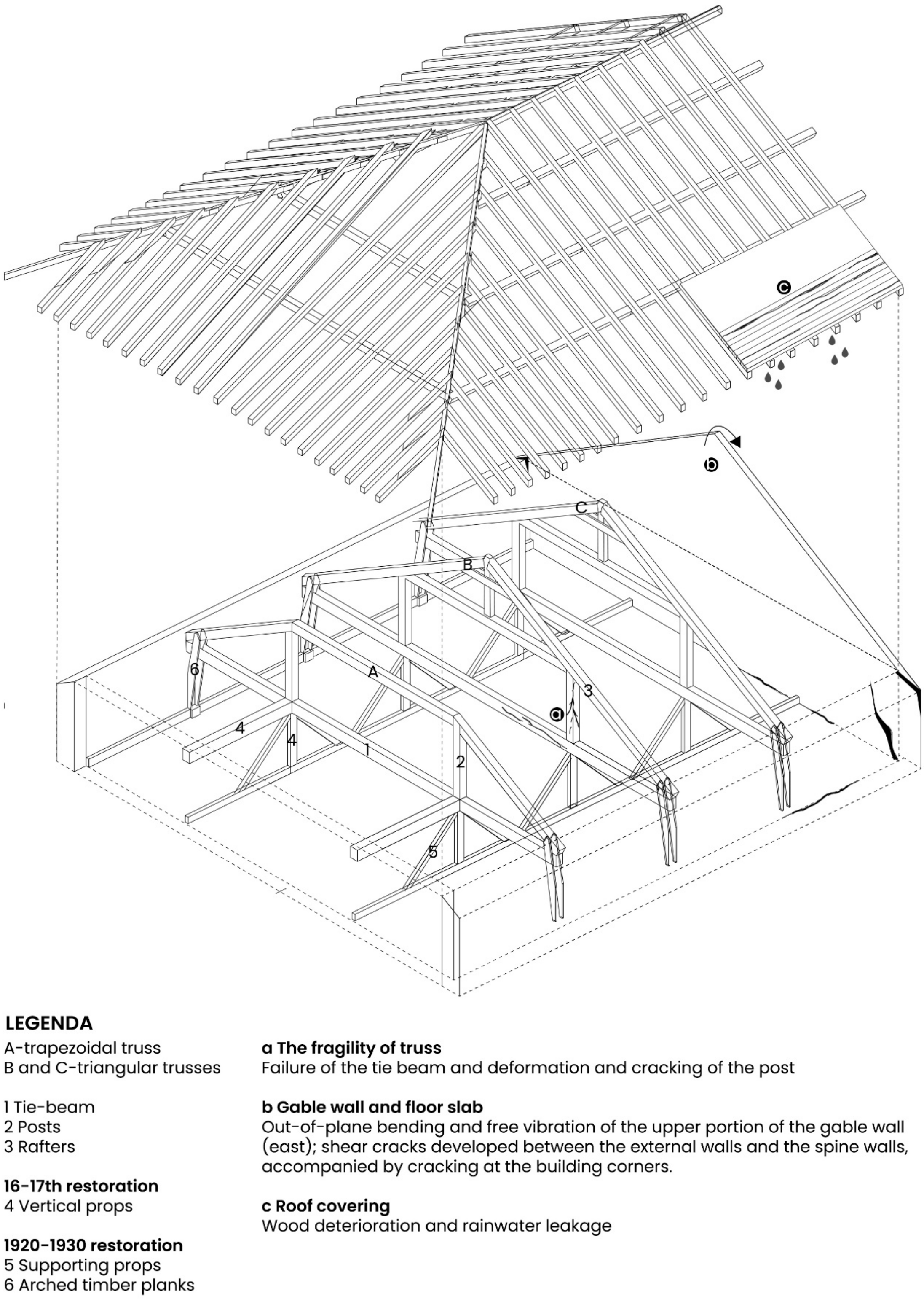


Figure 6.21: Axonometric view of the roof and damage analysis

The issues can be summarized under three main categories (Figure 6.21). Firstly, problems with the roof trusses themselves primarily manifested as inherent structural fragility. The investigation found that trusses were operating in isolation, with missing or failing lower chords in certain sections. This led to severe deflection of some post, and in some cases, fractures.

Secondly, issues with the gables and floor slabs, primarily characterized by concentrated loads. The eastern external gable, exceeding neighboring buildings by 4 meters in height, exhibits upward curvature and free vibration at its apex. This predisposes the trusses to mutual compression, compromising structural integrity. Concurrently, shear cracks, corner fissures, and wall displacement have emerged in both the external walls and ridge wall. The floor structure, supported by timber beams and overlaid with heavy Palladiana trusses, lacks both planar rigidity and effective connection to the external walls.

Finally, the roof presents issues primarily characterized by timber deterioration. Consequently, rainwater ingress further damages internal structures. The roof comprises scorzoni battens and partially decayed boards, arranged parallel to the roof slope. This orientation provides no rigidity in the direction of the roof pitch.[89]

6.2.3 Logic of the Intervention Strategy

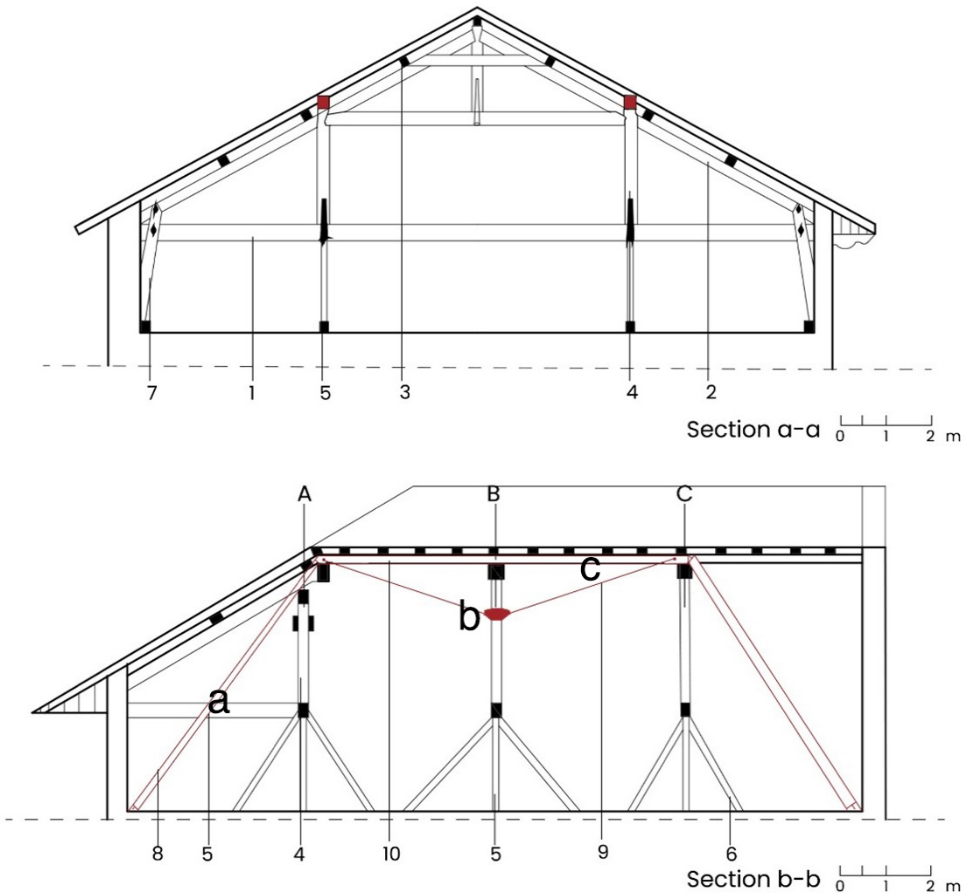
Following a comprehensive building survey, the restoration approach selected was layered/superimposed reinforcement (integrazione stratificata o affiancata). This entails collaborative strengthening of the existing structure, preserving as much of the original fabric as possible through minimal intervention.

On the one hand, the original components hold significant historical value. On the other hand, while the structure presented significant issues, these could be resolved through new structural design, thereby avoiding extensive demolition. The fundamental

[89] Ibid.

objective of this restoration was to enhance seismic efficiency.

Based on the structural diagnosis, the overall restoration strategy can be articulated into three main parts: the enhancement of the overall integrity of the truss system, the strengthening of the roof trusses, and the improvement of the structural interaction between floors and masonry walls.



LEGENDA
1 Tie-beam
2 Rafters
3 Purlins
4 Posts

16-17th restoration
5 Vertical props

1920-1930 restoration
6 Supporting props (puntelli).
7 Arched timber planks (tavoloni formati come centine ad arco)

1986 restoration
a Steel components are employed for the fir (abete) diagonal braces and thrust-counteracting elements
b The lower chord chain (catena inferiore)
c The upper chord central chain (catena superiore).

Figure 6.22: Section of the roof after restoration

Firstly, the reinforcement of the roof structure primarily involves the addition of east-west trusses and metal tie rods (Figure 6.22 section b-b). Their function is crucial, not only providing horizontal restraint to the external walls but also enhancing the overall integrity of the truss system. The new trusses are presented in an exposed, unobscured manner, continuing the logic of adaptive evolution over four centuries while maintaining visual distinguishability from the old components. The newly installed structure preserves the stability of the traditional framework without imitating the historical elements, thus not compromising the historical information. It exists as a 'layered superimposed system'.[90]

Concurrently, the project restored the historic trusses (Figure 6.22 section a-a). This involved repairing the fractured or severely deflected posts, reinforcing and partially replacing the catene (lower chords), installing new puntelli (support struts) to improve deflection control, and replacing the truss's upper chord purlins with new timber beams. Consequently, the integrity and stability of the entire roof structure have been preserved.

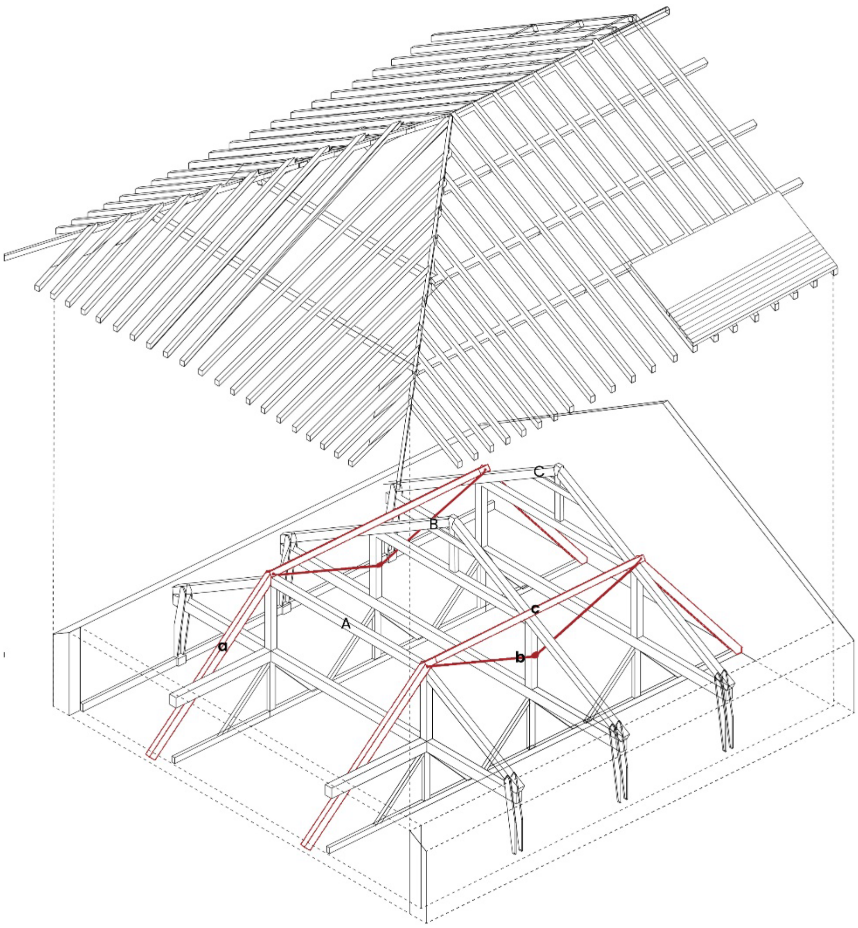
Figure 6.23: Interior view of the roof after completion of the restoration, showing the new transverse trusses.

Besides reinforcing the roof structure, the most crucial aspect of this project was establishing a complete metal bridging system at the floor levels (Figure 6.24). The purpose is to create a continuous and reliable tie-in system at floor level, thereby enhancing the overall synergistic effect between the walls.

[90] Ibid.,275

Figure 6.24: Left: Installation of the steel ring-tie at the roof level during execution. Centre: Installation of the steel ring-tie at the intermediate floor level during execution. Right: Corner connection between the floor-level ring-tie and the external anchor plate.

Finally, the roof restoration involved replacing one-third of the irreparable rafters with a double-layer timber system: the first layer replaced damaged components, while the second layer provided an integral surface layer, with localized adjustments to the battens and covering.



LEGENDA

1986 restoration

a Steel components are employed for the fir (abete) diagonal braces and thrust-counteracting elements
b The lower chord chain (catena inferiore)
c The upper chord central chain (catena superiore).

Figure 6.25: Axonometric view of the roof after restoration

6.2.4 Critical Reflection

The roof restoration of Palazzo Villabruna exemplifies a typical approach within Italy's heritage building sector: ‘affiancamento’ (parallel reinforcement), where structural strengthening is integrated as part of the building assembly's restoration. Structural performance itself constitutes an element of cultural heritage conservation. The metal ring-tie system, newly added transverse trusses, and localised timber repairs collectively form a comprehensive structural strategy. This not only restores the roof system's integrity but also enhances the entire building's seismic resilience, establishing a reliable foundation for future use and preservation.

In this case, whether visible or concealed, affiancamento’ represents a conservation-compliant structural strategy. Employing a layered, identifiable, and reversible reinforcement system with minimal intervention, it resolves structural issues and enhances seismic performance while preserving historical layers. The original structural fabric remains clearly discernible, enabling the historic building to attain contemporary structural integrity without compromising its authenticity.

Chapter 7 Case Studies—Timber-Structure Restoration in China

This chapter discusses the conservation of Chinese timber architecture from the perspective of authenticity. In the Chinese context, authenticity is not limited to material fabric or structural performance. It is closely related to the internal construction system and the order of craft practices. As shown in the typological analysis in Chapter 2, the Chinese timber system emphasizes joint configuration and hierarchical relationships between components. Each type of element usually follows relatively stable dimensional modules and rules of combination. Buildings of different scales are generated from basic components through proportional and hierarchical order.

Therefore, although both Eastern and Western timber structures widely use mortise-and-tenon joints, China and Italy do not differ only in their structural requirements for joint performance. In actual conservation practice, large-scale timber interventions in China and Italy also show different priorities in terms of structural logic and craft order. In the Chinese context, for example, the relationship between bracket sets (dougong) and roof overhangs discussed in Chapter 2, like Italian cases, embodies a long accumulation of empirical knowledge of statics and structural behavior. It reflects the knowledge embedded in traditional craft systems. More importantly, in Chinese timber architecture, joint construction and overall proportional order are not merely technical solutions but also constitute cultural identifiers. This is a fundamental characteristic of Chinese timber structures.

This chapter selects the Main Hall of Nanchan Temple and the East Main Hall of Foguang Temple as two Tang-dynasty case studies of major timber construction. Tang-dynasty large timber structures do not represent an independent structural type. They are a concentrated expression of the post-and-beam system in high-ranking buildings, in which the structural core lies in the beam–column framework and the hierarchical order of components.

At the same time, the Main Hall of Nanchan Temple and the East Main Hall of Foguang Temple were built using the same construction ruler. Both were designed and constructed with a dual modular system based on *cai-fen* and the construction ruler. These two Tang-dynasty timber buildings in the Wutai Mountain region reflect the sophistication and completeness of the *fashi* system at the peak of ancient Chinese architecture. They represent the earliest and most important extant physical evidence for the study of formal systems in ancient Chinese timber construction.[91]

Both buildings are over one thousand years old, and their survival is remarkable. More importantly, the different conservation approaches adopted in the modern period clearly reveal the phased characteristics and practical dilemmas of Chinese timber conservation under the framework of authenticity.[92]

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91 Zhang Rong, Study on the Reconstruction Background, Material Deployment, Component Analysis, and Architectural Spatial Layout of the Main Hall of Nanchan Temple (in Chinese), 23.

92 Songfeng Jing, Wei Wang, and Takeshi Masui, "Analysis for Conservation of the Timber-Framed Architectural Heritage in China and Japan from the Viewpoint of Authenticity," *Sustainability* 15, no. 1384 (2023): 7.

7.1 Nanchan Temple — Wutai County, Shanxi Province

7.1.1 Relevance of the Case

Figure 7.1: Location of Nanchan Temple

Nanchan Temple is located on an earthen ridge west of Li-jiazhuang Village in Yangbaixiang, Dongye Town, Wutai County, Xinzhou City, Shanxi Province, surrounded by mountains on all sides (Figure 7.1).

The temple faces south and is composed of a main courtyard, an eastern side courtyard, and a rear courtyard (Figure 7.2).[93] There are no surviving ancient textual records documenting the early history of Nanchan Temple. The available evidence is

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[93] Zhang Rong, Study on the Reconstruction Background…, 6.

limited to several stone inscriptions from the Ming and Qing dynasties and an ink inscription discovered on the underside of the flat beam on the west side of the central bay of the main hall. The inscription reads: “Rebuilt in the third year of Jianzhong of the Great Tang dynasty (AD 782) … respectfully recorded by Faxian and others.” This inscription indicates that the main hall was rebuilt in the third year of the Jianzhong reign (782).

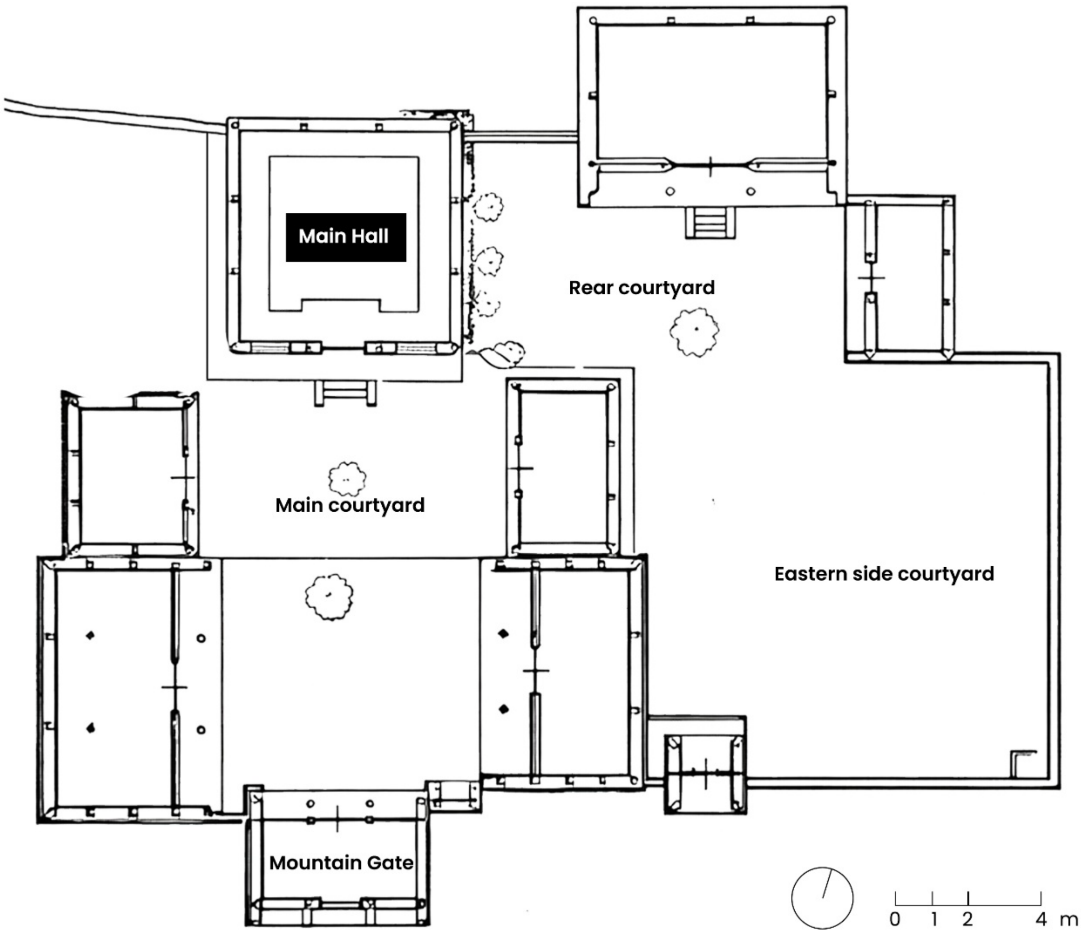

Figure 7.2: The plane of Nanchan Temple

On this basis, the Main Hall of Nanchan Temple is identified as the earliest surviving Chinese architectural structure with a relatively complete timber framework. It is also considered one of the earliest extant timber buildings in Asia and therefore holds significant importance in the history of Chinese architecture.

As discussed earlier, Chinese timber architecture is based on modular systems and proportional rules. The discovery of the Main Hall of Nanchan Temple therefore became direct physical evidence of the cai-fen modular system and the construction regulations of major timber structures. Its construction practices correspond in many aspects to the principles described in the Yingzao Fashi, while also exhibiting more flexible and distinctive methods. From the perspective of historical documentation, Nanchan Temple is identified as a Tang-dynasty building. However, field investigations show that its formal characteristics differ in certain respects from the theoretical features traditionally associated with Tang-dynasty architecture.

As a result, the conservation project extended over more than twenty years and was only implemented when the building had to be repaired due to earthquake damage. The key issue revealed by this conservation process is the following: when multiple historical layers coexist and available evidence is limited, should conservation prioritize preserving the condition at the time of discovery, or should it reconstruct an earlier stage based on historical interpretation? This decision directly exposes the tension within authenticity between the preservation of historical stratification and the re-presentation of formal and craft order.

The intervention on the Main Hall of Nanchan Temple, characterized by dismantling and reconstruction together with a hypothetical reconstruction approach, provides a representative case for observing the transformation of contemporary Chinese timber conservation from traditional repair practices toward a more systematic process of research, assessment, and implementation. At the same time, it offers new perspectives on timber conservation. Beyond structural and technical considerations, conservation practice must address how to balance material preservation, the continuity of constructional order, and the re-presentation of architectural form.

7.1.2 Structural System and Diagnostic Interpretation

The Main Hall of Nanchan Temple has three bays both in width and depth, with a nearly square plan, a single-evade hip-gable roof, and gentle roof slopes (Figure 7.3). On the interior Buddha altar, fourteen Tang-dynasty polychrome sculptures remain (originally seventeen), forming an impressive and finely crafted ensemble.[94]

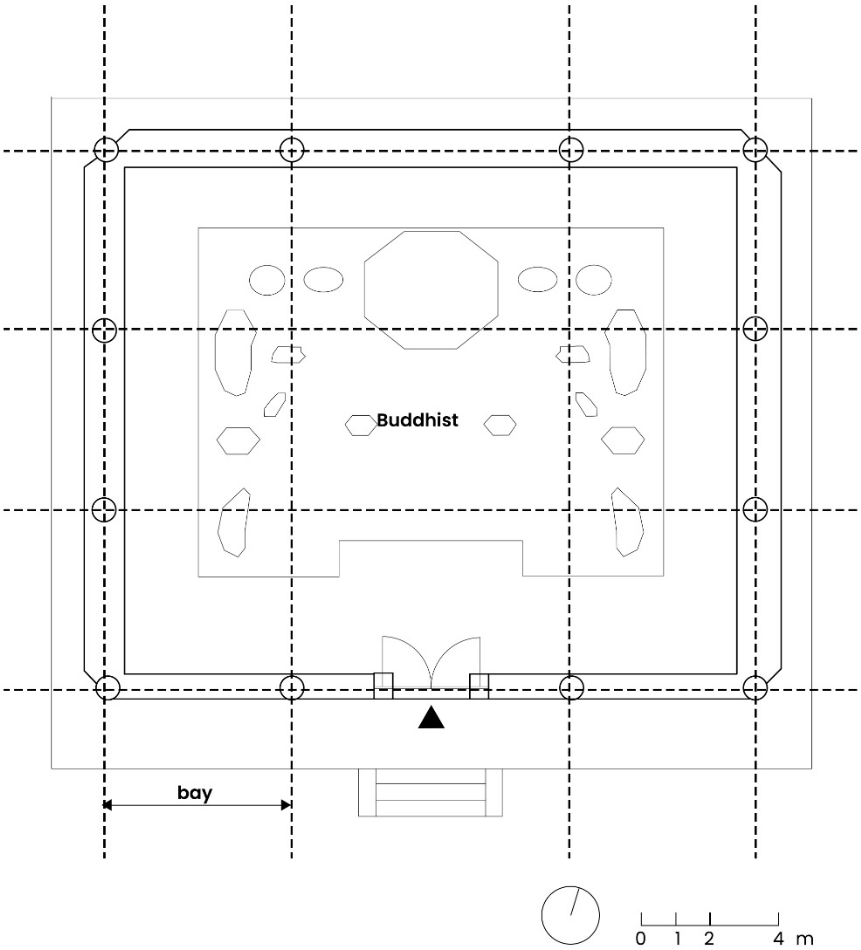

Figure 7.3: The plane of the Main Hall of Nanchan Temple

The roof structure of the Main Hall of Nanchan Temple Main Hall represents a typical Tang-dynasty construction technique. It adopts a four–rafter-bay roof system,[95] in which a single beam supports five purlins, combined with a common two-column

[94] Ibid., 6.

[95] In this roof system, the fú functions as the primary longitudinal load-bearing beam. Transversely placed purlins (tuán) rest on the beam, and rafters are laid longitudinally above the purlins. A rafter bay

structural scheme. This system is characterized by a simple structural configuration and robust, massive timber members.

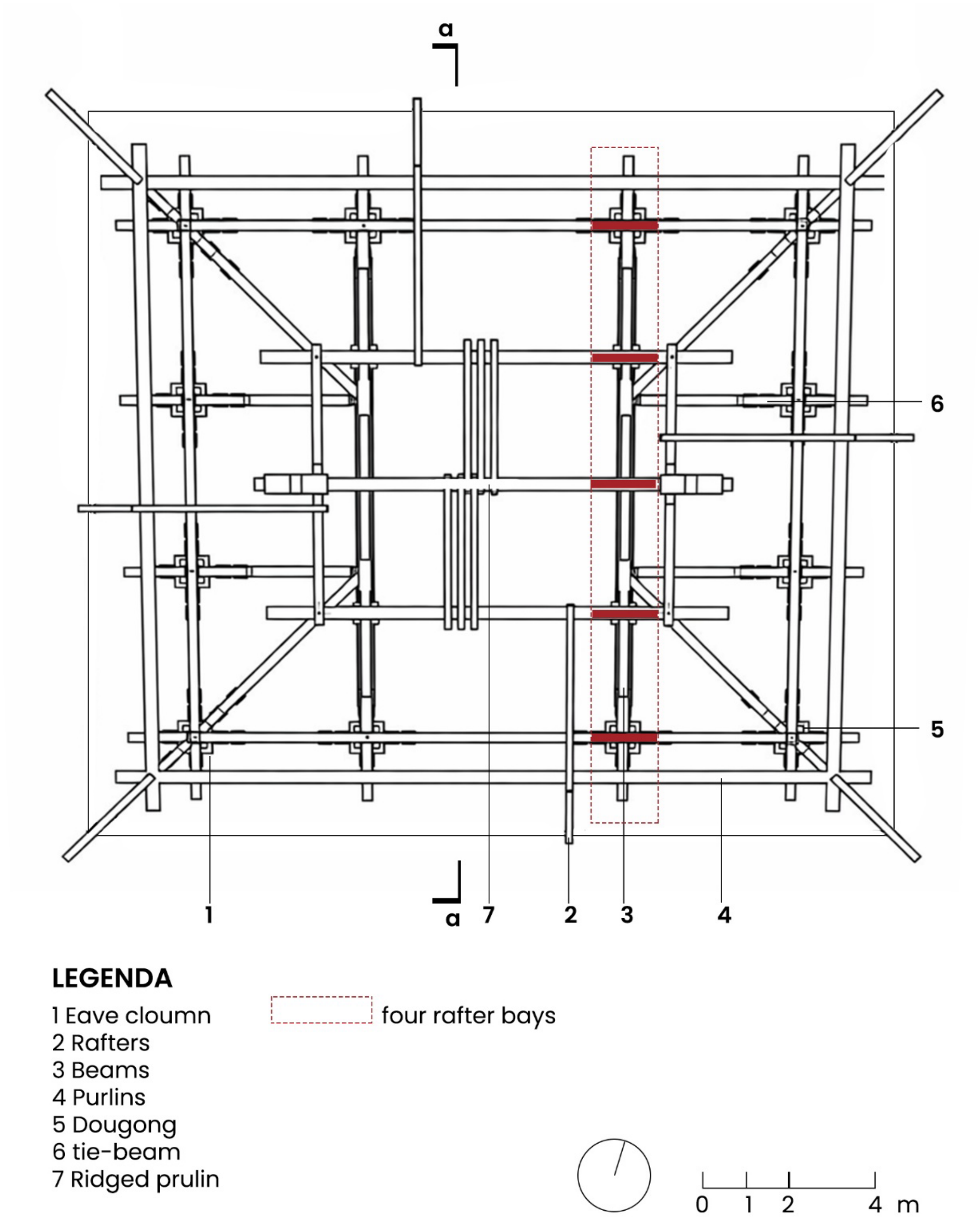

Figure 7.4: The plane of the roof structure

From its discovery to its conservation, this Tang-dynasty building underwent a

is defined as the group of rafters spanning between two adjacent purlins. In the Main Hall of Nanchan Temple, each beam supports four rafter bays, forming what is traditionally referred to as a four-rafter-bay beam roof system.

process lasting nearly twenty years. The figure below summarizes the overall conservation process based on the available documentation.[96]

TIME	Incident	RESULTS
1953	Nanchan Temple was discovered in Lizhuang Village, Wutai County, Shanxi Province, where surveys and research were conducted.	It is estimated that the Great Buddha Hall was constructed no later than the third year of the Jianzhong era of the Tang Dynasty (782 AD).
1953 .10	On-site inspection	The structure is already damaged and in urgent need of repair.
1954 .4	Mr Qi Yingtao of the Beijing Cultural Relics Organisation Committee submitted the Survey Report on Nanzhen Temple in Lizhuang Village, Wutai County, Shanxi Province, accompanied by a Preliminary Draft Plan for the Restoration of Nanzhen Temple's Main Hall.	Several architectural scholars advised against altering the existing structure without absolute certainty,and thus no restoration work was undertaken.
1961		In 1961, the main hall of Nanchan Temple was designated by the State Council as one of the first batch of National Key Cultural Relics Protection Units.
1966	Xingtai Earthquake	The main hall of Nanchan Temple suffered severe structural damage: its timber framework was warped and twisted, eaves tilted forward, and wooden components were dislodged from mortise joints and split open. The state of preservation is critically precarious.
1972	State Council's Reply Regarding the Urgent Repair and Conservation of Three National Key Cultural Heritage Sites Including the Yungang Grottoes	The Shanxi Provincial Cultural Relics Working Committee organised the necessary personnel, with Qi Yingtao overseeing the design of the restoration plan and Chai Zejun responsible for the implementation of the project.
1974.8-1975.8		Project Completion

Figure 7.5: The timeline of the restoration process of the Main Hall of Nanchan Temple

After Nanchan Temple was discovered in 1953 and its heritage value was confirmed, a series of academic studies and debates began on how it should be protected. The 1953 on-site survey had already identified structural damage in the building.

96 Zhang Rong, Study on the Reconstruction Background…, 6.

However, the 1954 Preliminary Restoration Plan for the Main Hall of Nanchan Temple was not approved. Several architectural scholars argued that the existing structure should not be altered without sufficient evidence.[97]

Figure 7.6: The facade of the Main Hall of Nanchan Temple, photographed in 1953

At a deeper level, this reflects the situation in 1954. At that time, Western discussions of authenticity had not yet entered China. The 1954 proposal was essentially a repair-oriented scheme. It aimed to “fix” the building based on craftsmen’s experience. It lacked an investigation and analysis of the building’s structural history and its historical layers. It also did not adopt an authenticity-based perspective. In this sense, the fact that the 1954 plan was not carried out can be seen as a timely prevention of potential loss.

Although the restoration proposal of 1954 was not implemented, the survey produced at that time still provide valuable evidence of the structural condition and historical stratification of the building.

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[97] Qun Zha, “Early Conservation Practices of China (I): A Comparative Study of Two Restoration Proposals for the Main Hall of Nanchan Temple,” *China Cultural Heritage*, no. 1 (2018): 85.

As shown in Figure 7.7, the eave projection[98] of the Main Hall of Nanchan Temple Main Hall is extremely limited, which is highly inconsistent with historical records describing the deep eaves characteristic of Tang-dynasty architecture. Moreover, distinct saw marks are visible at the ends of the eave rafters, indicating that the eave rafters were likely shortened during a previous repair campaign due to decay at the rafter tips.

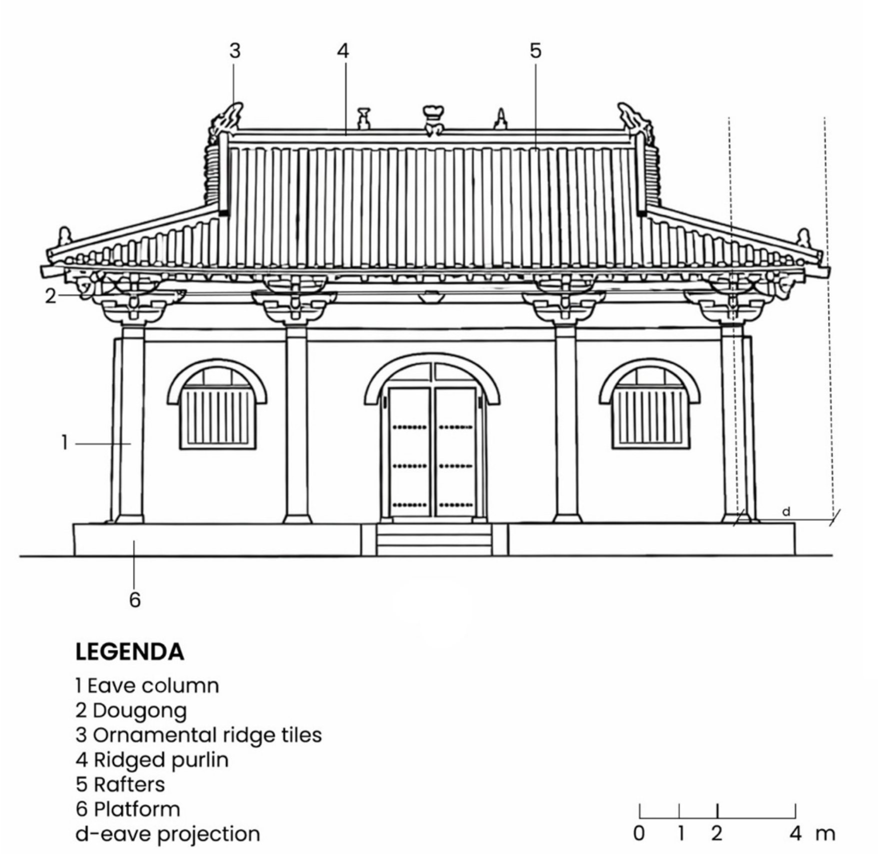

Figure 7.7: The front view of the Main Hall of Nanchan Temple before restoration

At the same time, the section view (Figure 7.8) shows that the main beam (the four–rafter-bay roof) is the primary load-bearing member. Over a long period, it developed serious deterioration, including bending, torsion, and increasing deflection. Before conservation, the eastern beam showed a deflection of up to 9 cm, while the western beam reached 8 cm. Diagonal cracking at the beam ends, where they extend

[98] The eave projection is defined as the horizontal distance measured from the centerline of the eave column to the rafter tip.

into the bracket sets, was particularly evident, indicating that the structure was on the verge of instability.

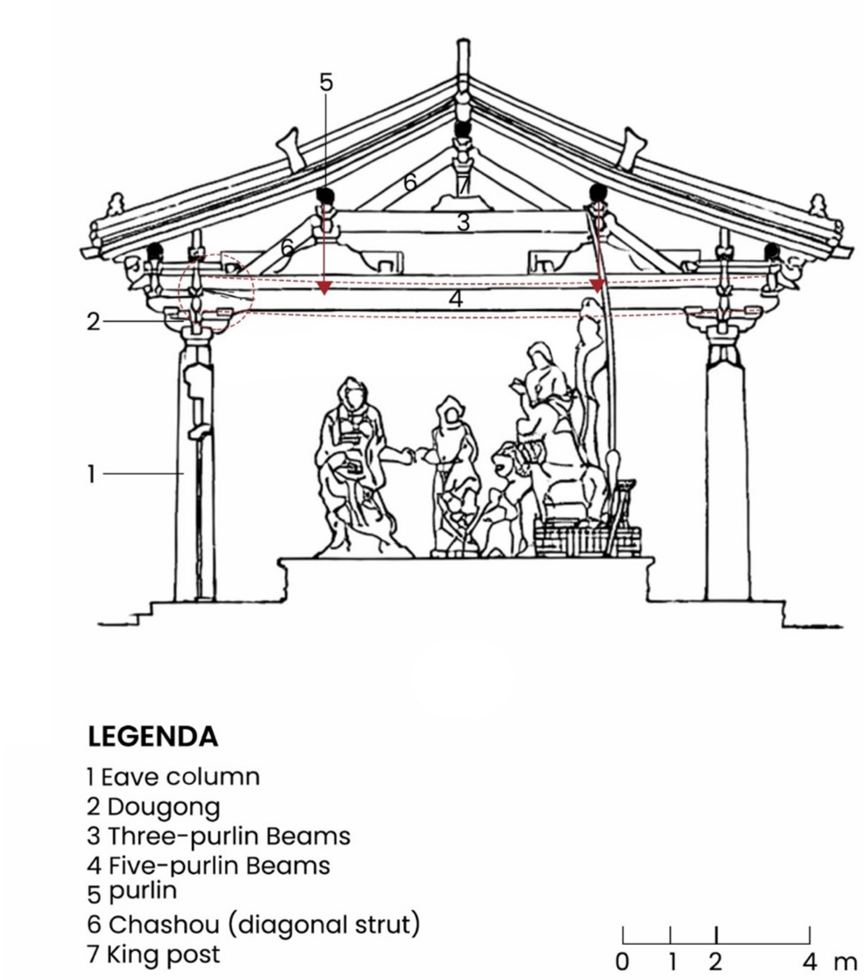

Figure 7.8: The cross-section a-a of the Main Hall of Nanchan Temple before restoration

Secondly, many building components exhibit cracking. For example, the nose (shuatou)[99] in the bracket (dougong) sets on the gable sides was originally carved from the end of the tie beam. Because the mortises at its junctions with the column-head tie beam and the secondary bracket (linggong)[100] are vertically misaligned, long-term loading caused cracks to develop along the direction of the wood grain (Figure 7.9).

99 Shuatou, literally, "mocking" "head" or "top", is a component part of the dougong (bracket-set) located above the uppermost layer of huagong or ang. The shuatou protrudes from the center of the dougong, intersecting with the linggong, which is perpendicular to it.
100 Linggong is a horizontal bracket arm within the dougong system.

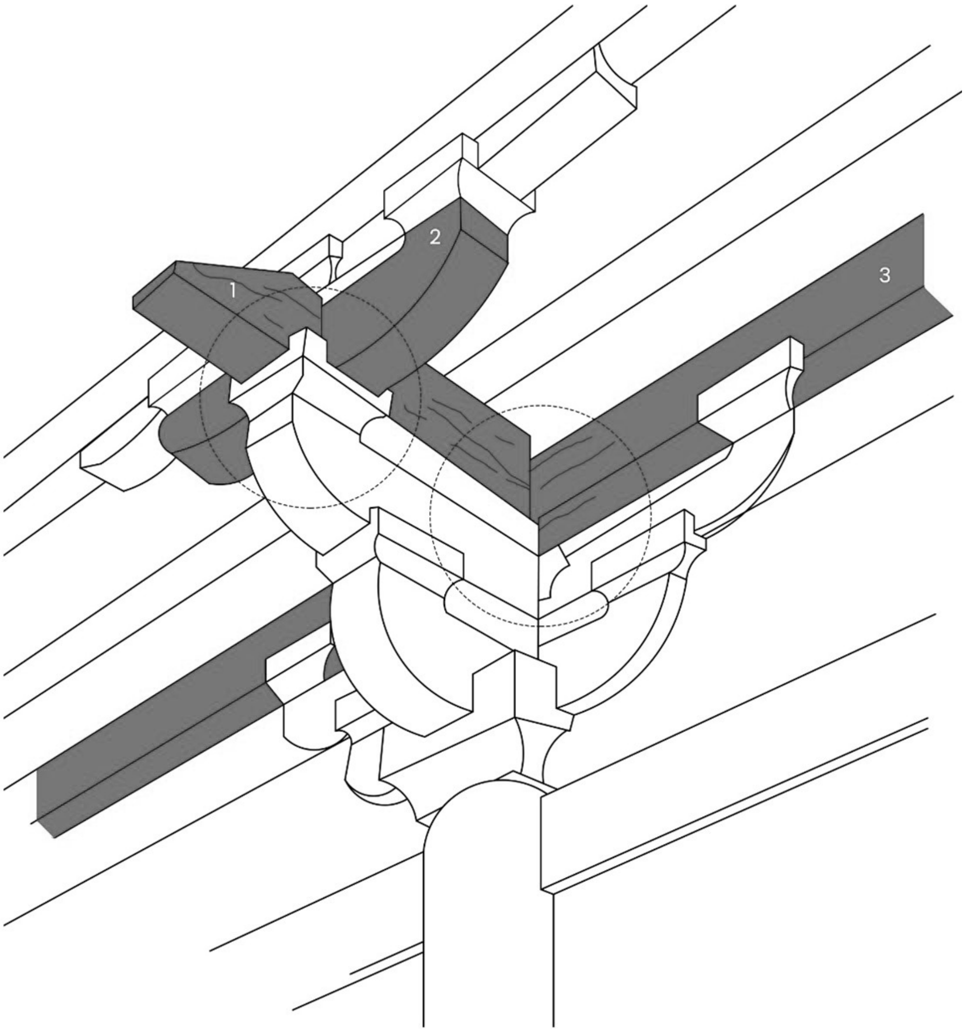

Figure 7.9: Composition and cracking of the gable-side Chinese bracket before restoration

7.1.3 Logic of the Intervention Strategy

Due to earthquakes and many years of neglected maintenance, the conservation task at Nanchan Temple was extensive. How the temple should be repaired became the central issue in the discussions of the 1954 and 1972 restoration proposals. Ultimately, the 1972 project did not adopt the 1954 scheme.

On the one hand, international charters on authenticity had a profound influence on conservation thinking in China. Although the theoretical framework was not yet fully developed, many architects, including Liang Sicheng, began to advocate preserving the existing condition and retaining original materials as much as possible. The 1954 proposal was essentially a repair-oriented approach. It aimed to restore the building based on craftsmen's experience, without considering historical stratification or authenticity.

On the other hand, given the extent of structural damage, reconstruction was unavoidable. In traditional Chinese architecture, the primary load-bearing structure is timber. However, reconstruction was no longer understood simply as rebuilding the structure with new timber following the original form. Instead, original components needed to be retained wherever possible. Replacing all elements with new materials would mean the building could no longer be regarded as a historic monument.

In the end, Nanchan Temple adopted the method of luojia chongxiu (dismantling and reconstruction). This approach involves completely dismantling the timber structure—including beams, columns, and bracket sets—repairing each component individually, and then reassembling them in their original positions. Before the mid-twentieth century, this method was widely regarded as an effective way to restore both the structural safety and the original appearance of historic timber buildings.

At the same time, the conservation of Nanchan Temple aimed to restore the building to a specific historical period. As discussed earlier in relation to timber joints and proportional systems, the beam–frame structure directly determines spatial layout, ritual order, and the craft characteristics of different periods.

Therefore, conservation practice in China often requires reconstructing the original form of a building as it existed in a particular historical phase, based on historical records, surviving physical traces, and component dimensions. On this basis, modular units, component proportions, and structural order are re-examined so that the building can be brought as close as possible to the construction system of its original period. In this context, a timber building is not only a structure for use, but also an important material carrier for historical and cultural verification.

In summary, the 1972 restoration sought, under the principle of minimal intervention, to retain original materials as much as possible while restoring the building to an historically correct form. In doing so, it aimed to ensure the continuity of traditional construction knowledge and craft culture.

Figure 7.10: The Main Hall of Nanchan Temple after restoration

7.1.3.1 Reconstruction of the roof overhang and door–window system

Based on the elevation after the completion of the 1972 restoration (Figure 7.11), several changes can be identified. The roof overhang became longer, the doors and windows were replaced with Tang-style forms, the platform (yuetai) was reconstructed, and the decorative tiles on the ridge were altered. From the section, it can also be observed that the dwarf columns were removed.

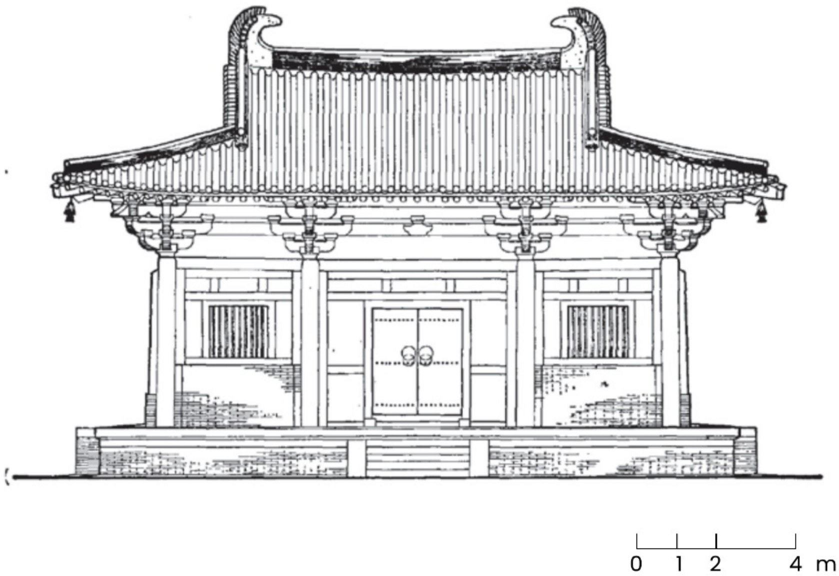

Figure 7.11: The front view of the Main Hall of Nanchan Temple after restoration

The 1953 and 1972 schemes proposed different restoration lengths for the roof overhang. The 1954 restoration design was based on dimensions visible on site. Parameters such as rafter diameter, rafter spacing, and roof curvature were estimated accordingly. However, due to the lack of systematic surveying and an understanding of historical measurement systems, the calculated rafter spacing was approximately 225 cm.

In contrast, the 1974 restoration was carried out based on comprehensive surveying and a renewed study of the relationship between rafters and roof overhangs. Using Tang-dynasty measurement systems and structural logic as references, the rafter spacing was corrected to 230–240 cm. On this basis, the proportional relationship between rafter spacing and the cai-fen module was established.

The differences between the two restorations mainly stem from methodological approaches. The 1954 scheme relied primarily on experiential judgment based on existing conditions, whereas the 1974 restoration employed systematic surveying and comparison with Tang-dynasty measurement systems. This resulted in a rafter spacing closer to the original condition (approximately 234 cm). This comparison reflects the transition in the conservation of the Main Hall of Nanchan Temple from experience-based judgment toward more scientific and institutionalized methods of measurement and analysis.[101]

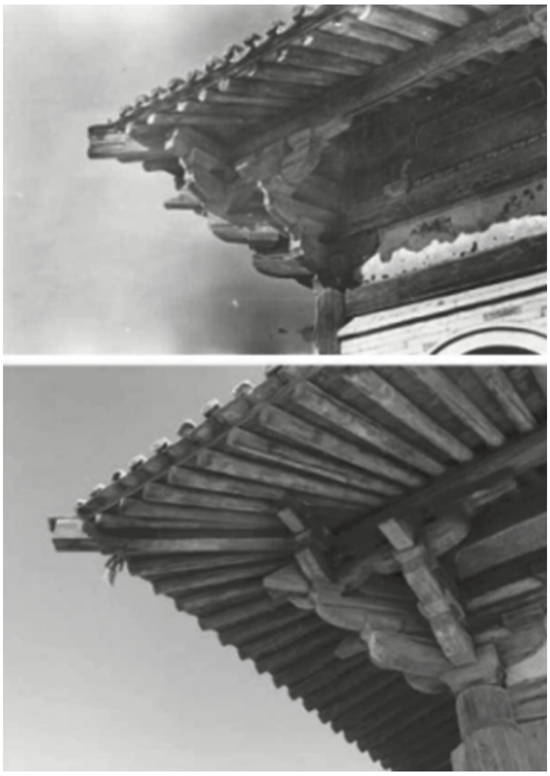

Figure 7.12: Top: The eaves of the main hall photographed in 1953; Bottom: The eaves of the main hall following restoration in 1974

7.1.3.2 Reinforcement of the overall structural system

The first aspect concerns the repair and reinforcement of individual timber components. Because the beams are subject to complex stress conditions, the reinforcement design is needed to account for both load transfer and the mechanical properties of the historic material. During construction, disturbances to the existing stress state of the timber were minimized in order to ensure more stable strengthening effects.

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[101] Zha, "Early Conservation Practices of China (I)," 85.

For the four-rafter beam with excessive deflection, the 1974 restoration first adopted straightening measures to restore the basic alignment between the beam ends and their mortise joints. The western beam was adjusted to within 3 cm of straightness and was therefore able to continue carrying load (Figure 7.13).

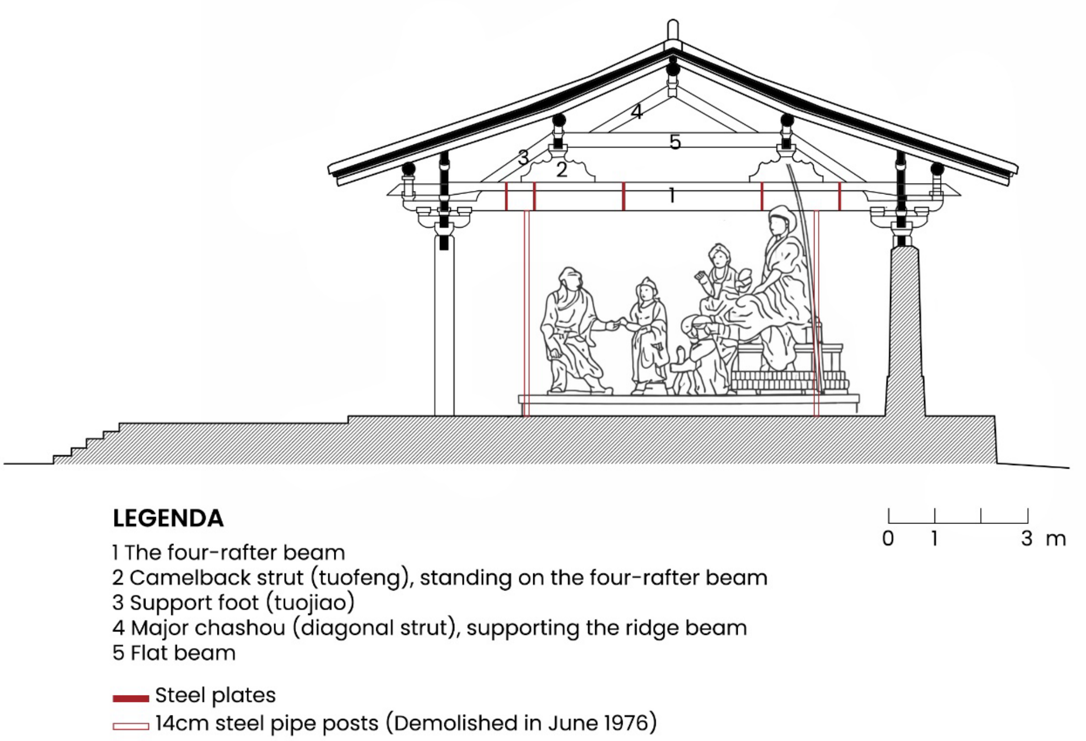


Figure 7.13: The cross-section a-a of the Main Hall of Nanchan Temple after restoration

However, the eastern main beam could only be straightened to a residual deflection of 5 cm and could not be further corrected. On this basis, systematic chemical reinforcement was carried out. The reinforcement process involved first sealing the cracks by epoxy resin injection. Iron nails and steel plates were then embedded into the beam to work together with the timber as a composite load-bearing system, and iron hoops were applied for additional confinement.

For the reinforced beams, twelve sets of steel plates were arranged along the length of the eastern main beam, while ten sets were installed on the western beam. The steel plates had a cross section of 7 × 0.5 cm (Figure 7.14).

Figure 7.14: The main beam after restoration

To ensure structural safety, two steel pipe posts, each 14 cm in diameter, were added beneath the underside of each main beam after installation. During construction, it was considered that the front post affected the visual experience for visitors. Therefore, in June 1976, the front additional steel post was removed.[102]

Another issue concerns the treatment of the king post (Zhuru).[103] As shown in the section (Figure 7.13), the section after the 1972 restoration no longer includes king posts.

The 1954 scheme chose to retain the king post. Based on observations of other columns, it inferred that the originally round king posts should be reshaped to match the square form of the other columns. This approach essentially represented an experience-based repair aimed at maintaining the existing condition. It neither addressed the structural risks inherent in the columns themselves nor offered a well-founded judgment based on historical structural logic.

[102] Ibid.
[103] The Zhuru (king post) is a short vertical post positioned on the horizontal beam.

By contrast, the 1974 scheme decided to remove the inclined columns and the king posts. First, during construction, the removal of roof tiles caused this group of components to become disengaged, yet the beam frame did not collapse. At the same time, the king posts were found not to be connected to the beam frame through mortise-and-tenon joints. On this basis, it was concluded that the king posts did not play a load-bearing role.[104]

Figure 7.15: Left: Photograph of the eave pillar taken in 1953; Right: Photograph of the repaired cross-braces taken in 2014

More importantly, through systematic structural calculations and analysis, it was determined that the load-bearing capacity of the chashou (diagonal strut)[105] was sufficient and did not require support from king posts. The king posts were therefore removed. To further enhance the stability of the diagonal strut, steel tie rods were installed at the bases of the two members, closely attached to the flat beam. This measure reduced the outward horizontal thrust of the diagonal strut and helped extend the service life of the building.

From a technical standpoint, areas of the timber structure that exhibited cracking or were prone to movement were reinforced using metal components and chemical methods (Figure 7.16). For example, when reinforcing cracks at beam ends, epoxy resin was first injected to seal and consolidate the fissures. After curing, two iron hoops were

[104] Zha, "Early Conservation Practices of China (I)," 81.
[105] Major chashou (diagonal strut), supporting the ridge beam

installed externally. The injection method and materials were the same as those used for treating cracks in the main beams.

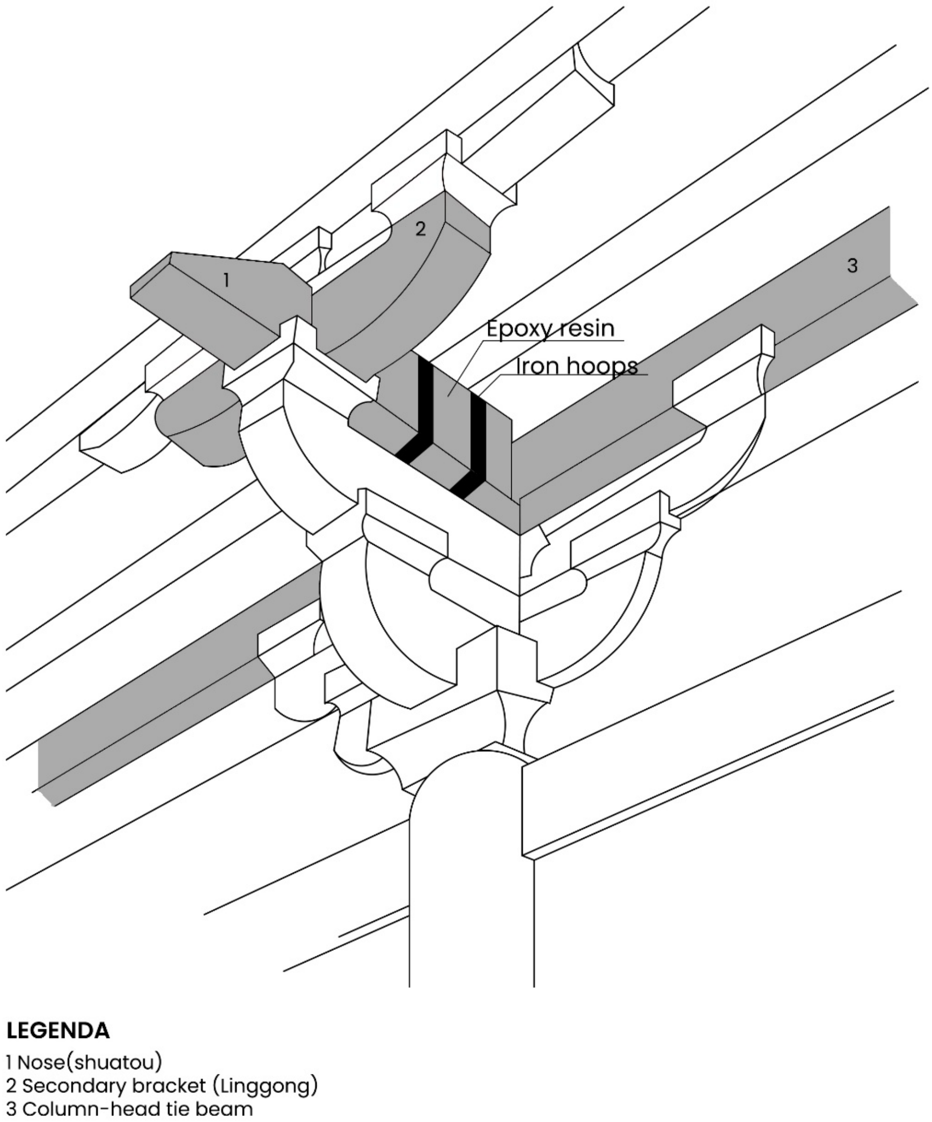


Figure 7.16: The gable-side Chinese bracket after restoration

Larger cracks found in other components—such as brackets, tie beams, blocks, horizontal tie beam (lan'e), diagonal strut (chashou), and struts—were reinforced using the same method (Figure 7.17). Purlins were secured with iron clamp nails to prevent rotation. In addition, near the four-rafter beams within each bay, one rafter in each structural step was selected and fixed to the purlin with bolts. After installation, this reinforced rafter was referred to as a "tie-rod rafter."

LEGENDA

1 No intercolumnar bracket sets between the two columns
2 Lan'e (horizontal tie beam)
3 Column-head bracket assembly (pu-zuo)
4 Column-head tie beam (zhutou fang)
5 Dingfu (beam), seated on the four-rafter beam, with its outer end supported by the column-head bracket set
6 The four-rafter beam
7 Camelback strut (tuofeng), standing on the four-rafter beam
8 Support foot (tuojiao)
9 Major chashou (diagonal strut), supporting the ridge beam
10 Flat beam
11 Purlins laid out at equal spacing on the column-head tie beams
12 Corner beam
13 Chiwei (ridge-end ornament), reconstructed in recent years based on scholarly research

Figure 7.17: Axonometric view of the main hall of Nanchan Temple after restoration

7.1.4 Critical Reflection

The 1974 restoration was carried out based on comprehensive surveying, structural investigation, and dimensional analysis. It adopted a reconstruction strategy oriented toward the "restoration of Tang-dynasty construction principles." This case suggests that, for historic timber buildings, the issue of authenticity in conservation is not limited to the retention of original materials, nor is it equivalent to the recovery of structural performance alone.

More critically, the proportional relationships, spatial order, joint details, and construction logic embodied in historic structures constitute essential layers of information within timber architecture as cultural heritage. When conservation adopts a specific historical phase as its target for selective reconstruction, authenticity inevitably becomes a matter of balancing materials, structural behavior, and constructional order.

To date, extensive research has been accumulated over several decades on the form, dimensions, and construction practices of the Main Hall of Nanchan Temple.

For example, scholars have used survey data to reconstruct Tang-dynasty construction rulers and to re-establish the dimensions of the beam–frame system, the proportions of the column grid, and the cai-fen modular system. Comparative studies based on paintings and iconographic sources have been used to examine the spatial layout of Nanchan Temple in relation to Foguang Temple. Measured data have supported analyses of key construction elements, such as column spacing, beam depth, and roof curvature, to infer their original configurations. In addition, multidisciplinary approaches—including archaeology, iconography, construction history, and studies of measurement systems—have been employed to reconstruct the dimensional framework and construction logic of Tang-dynasty main halls. At the same time, in-depth research has also been conducted on interior remains of the Main Hall of Nanchan Temple, such as sculpture and painted decoration.[106]

[106] Zhang Rong, Study on the Reconstruction Background…, 5-23.

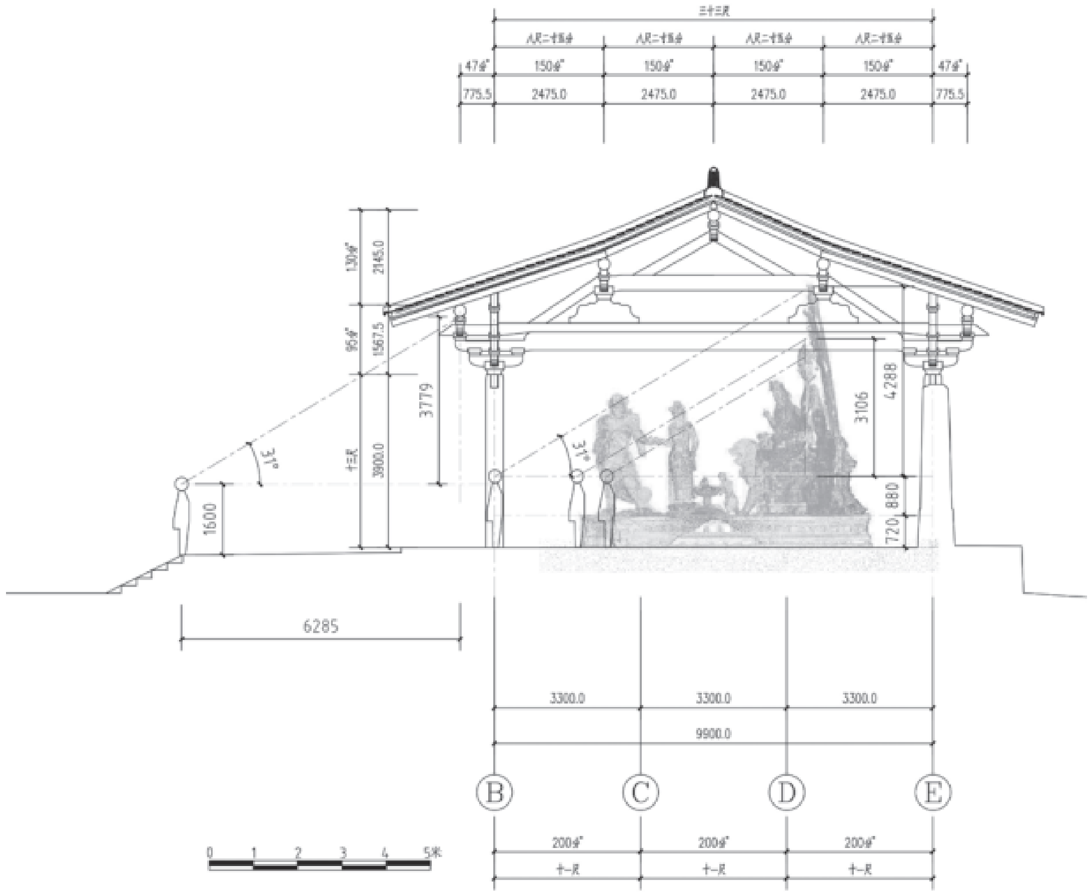


Figure 7.18: Spatial Layout and Visual Axis Analysis of the Main Hall of Nanchan Temple Main Hall

This demonstrates that so-called “structural authenticity” in timber conservation is not a purely engineering issue. It is closely related to the spatial order generated by the structure and to its cultural value as a carrier of historical knowledge. The maintenance of structural authenticity also provides the necessary basis for further research on space, historical stratification, and associated artistic remains. It therefore cannot be reduced to the single objective of preserving original materials alone.

At the same time, in the conservation of Nanchan Temple, severely deformed or damaged components—such as inclined columns, the four-kan beams, shuatou, and bracket sets—were treated through a strategy of “minimal replacement combined with local reinforcement.” This approach reflects the influence of Western conservation thinking, in which the retention of original materials is considered as important as the reconstruction of form. However, as discussed above, some reinforcement measures rely on metal elements to restrain and stabilize the original timber components. While such interventions improve short-term structural stability, they may also introduce load-transfer mechanisms and constructional expressions that are not fully consistent with the traditional mortise-and-tenon system. As a result, new tensions may arise between materials, structural behavior, and construction tradition.

How to further assess the impact of such metal reinforcements on the original functioning of joints, their reversibility, and the legibility of constructional logic—while ensuring structural safety—and how to explore alternative solutions more consistent with the logic of timber structures remain issues that merit continued discussion and refinement in future research and practice.

7.2 Foguang Temple East Hall — Wutai County, Shanxi Province

7.2.1 Relevance of the Case

Figure 7.19: Location of Foguang Temple

Foguang Temple is in Foguang Village, Doucun Town, Wutai County, Xinzhou City, Shanxi Province. The site sits on a west-facing slope, with the complex oriented along an east–west axis, facing west.

Adapting to the terrain, the temple is arranged on three stepped terraces rising from west to east (Figure 7.20).The first terrace is relatively wide, with the Hall of Wenshu on the north side, built in the fifteenth year of the Jin Tianhui reign (1137), and the Ming-dynasty rebuilt Hall of the Jialan on the south. A stone sutra pillar erected in the fourth year of the Tang Qianfu reign (877) stands in the Centre. The second terrace contains two side courtyards arranged to the north and south. The third terrace takes advantage of the natural slope and is formed by a tall retaining wall, creating a height difference of about 13 meters. Steep steps ascend through the center to the upper platform, on which stands the renowned Tang-dynasty Main Hall (the East Hall).

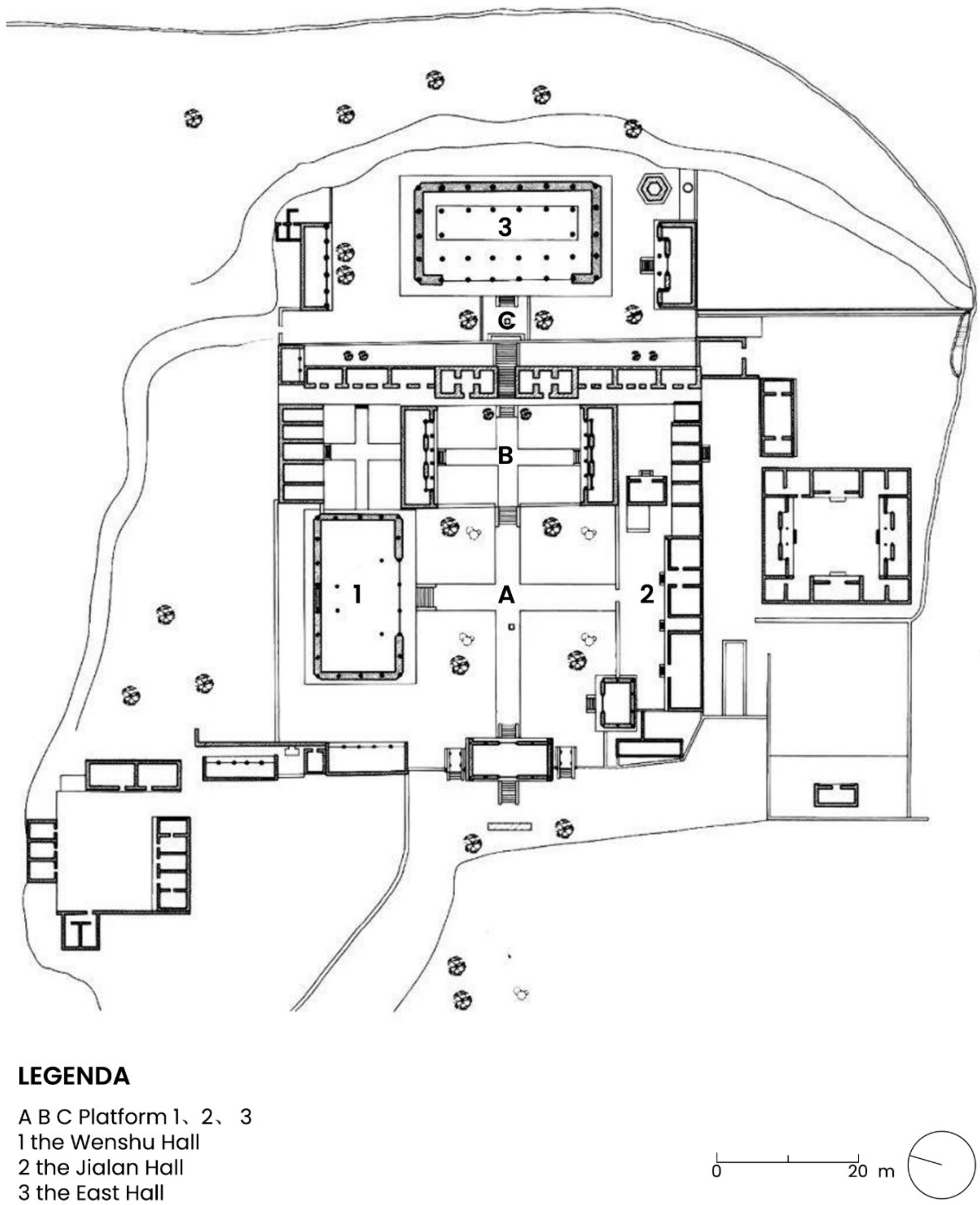


Figure7.20: Plane of the Foguang Temple

The East Main Hall of Foguang Temple is selected as the second case study in this chapter not only because it is the largest extant Tang-dynasty timber building with an exceptionally high degree of preservation, but more importantly because it represents a controversial yet analytically significant conservation path in contemporary Chinese timber heritage practice. Under a framework that strongly emphasizes material authenticity and historical integrity, conservation decisions for the East Main Hall have long tended toward extreme caution, with large-scale structural intervention deliberately postponed for decades. This approach makes the East Main Hall of Foguang Temple a key case for examining how authenticity goals shape the boundaries of intervention, while also revealing the potential risks and dilemmas that authenticity discourse may generate in practical conservation.

From a structural perspective, the East Main Hall embodies a mature form of Tang-dynasty major timber construction. Its authenticity is reflected not only in the high proportion of surviving historic materials, but also in the intact preservation of the hierarchical organization of the beam–column framework, joint behavior, and the overall proportional and constructional order. For this reason, any large-scale replacement, reconstruction, or forced reinforcement could result in irreversible loss of historical information. In other words, the hall's "high degree of integrity" constitutes both its core heritage value and the primary constraint on intervention decisions, placing the building in a condition of inherent tension between authenticity and structural risk management.

Therefore, the conservation of Foguang Temple is essentially an ongoing inquiry into how structural risk and progressive deterioration should be identified, defined, and addressed under the principle of minimal intervention when material authenticity and historical integrity are given the highest priority.

7.2.2 Structural System and Diagnostic Interpretation

The Main Hall (East Hall) of Foguang Temple is the largest surviving Tang-dynasty timber building in China. It is also the earliest extant example of a wudian (hipped) roof in China and the hall with the deepest bracket-set projection among surviving Tang and Song buildings.[107]

The plan of the East Hall (Figure 7.21) follows the jinxiang douditang layout, in which an inner and an outer ring of columns define the spatial configuration. The Buddha altar is placed within the inner bay enclosed by the inner columns, and a five-bay fan-shaped wall is built between the rear inner columns.

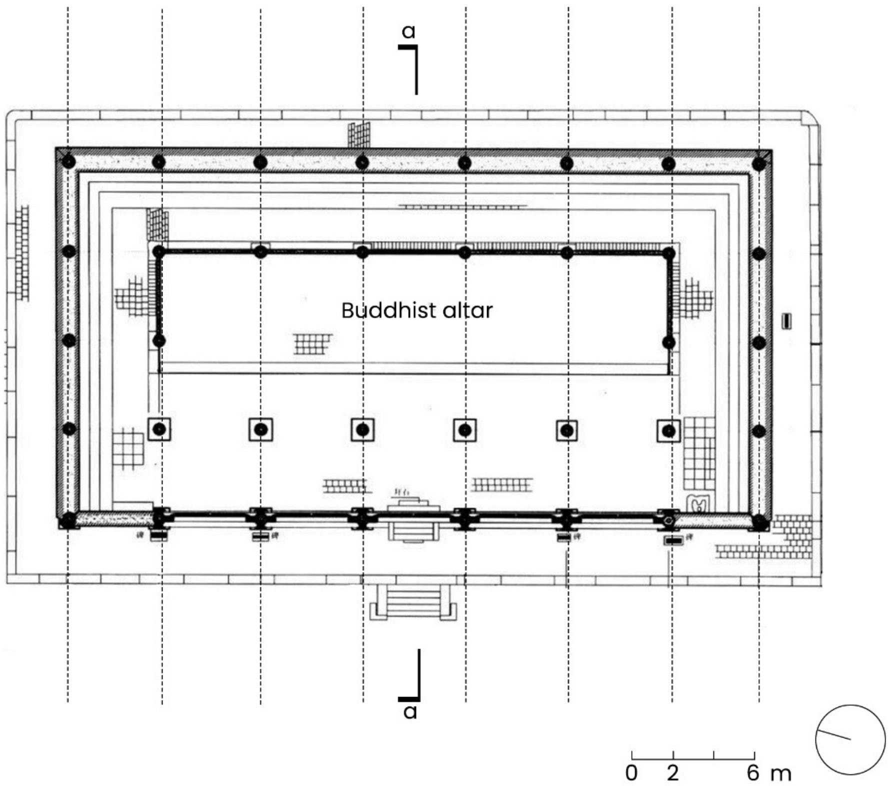
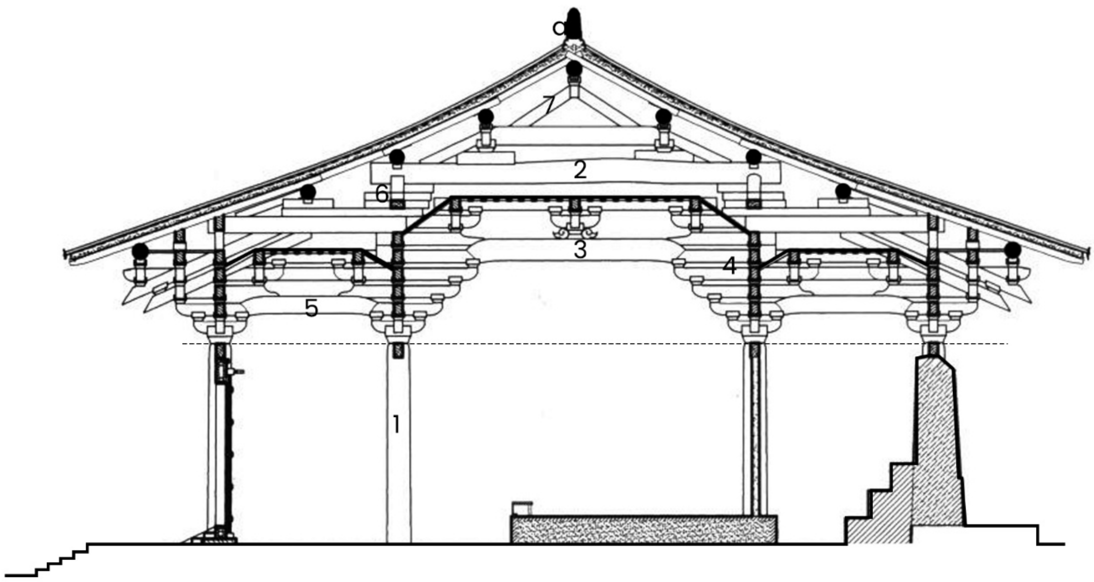


Figure7.21: The plane of the East Hall

[107] Li Guangjie, *Viewing Chinese Ancient Architecture in Shanxi* (Taiyuan: Sanjin Publishing House, 2023), 75–80. (in Chinese)

From the cross section (Figure 7.22), the inner and outer columns are of equal height, corresponding to what traditional building manuals describe as the "hall type" (diantang zuo).



LEGENDA

1 Columns
2 Hidden beam (caofu) are located above the ping'an ceiling. As they are not visible from the ground, they are left undecorated.
3 Exposed beam (mingfu) is a visible main beam spanning four rafters. Inscriptions recording donors' names and dates from the Tang dynasty were found beneath the beam.
4 Bracket (dougong) construction consists of multiple stacked dingtou bracket arms. It provides significant support to the main beam and reduces shear forces at the beam ends.
5 Secondary beam (rufang)
6 Rough brackets (Caogong) are located above the ping'an ceiling. As they are not visible from the ground, they are left undecorated.
7 Chashou functions as an inclined strut, supporting the ridge beam and distributing its load toward both ends to reduce stress concentration.

Figure7.22: The cross-section a-a of the East Hall

Above them is a coffered ceiling composed of small square panels, with the ceiling of the inner bay set higher than that of the outer bay (the space between the inner and outer columns), thereby creating a larger central space. On both sides of the ceiling, inclined boarding conceals the rafters, forming a trapezoidal "minor dome."[108]

Figure 7.23: The cross-section a-a of the East Hall

As shown in Figure 7.23, the structure of the East Main Hall generates a distinctive spatial order. In traditional design, structure, space, visual perception, and religious meaning are closely integrated. For example, when a visitor approaches the hall, the building can be perceived from a comfortable horizontal line of sight. During the process of movement, the viewing angle does not need to change in order to grasp the overall timber structure of the hall. This is followed by the view of a complete set of Buddhist niches, then the full figure of the main Buddha, and finally a precise alignment with the eyes of the principal statue.[109]

[108] Jing, Wang, and Masui, "Analysis for Conservation of the Timber-Framed Architectural Heritage in China and Japan from the Viewpoint of Authenticity," 9.
[109] Zhang Rong, Study on the Reconstruction Background…, 18.

In June 1937, guided by a depiction of Mount Wutai in a Tang-dynasty mural reproduced in the Dunhuang Grottoes Illustrated Catalogue, Liang Sicheng and Lin Huiyin travelled deep into the mountains of Shanxi and rediscovered this ancient temple, long hidden for centuries. And they identified an ink inscription left beneath the main purlin on the north side of the building, confirming that the hall was constructed in the eleventh year of the Tang Dazhong reign (857). It records that the building was funded by a Buddhist laywoman from Chang'an named Ning Gongyu.[110] Historically, the interior structural components of the temple had preserved their original Tang-dynasty form, giving the building exceptional value and a high degree of authenticity.

TIME	MEASURES	RESULTS
1937	Society for Research in Chinese architecture	Liang Sicheng, Lin Huiyin, Mo Zongjiang and Ji Yutang Photographs, mapping, discovery reports.
1951	Yanbei Heritage Study Group	Mo Zongjiang et al. Information on the Yanbei Heritage Expedition.
1964	State Administration of Cultural Heritag.	Shanxi Provincial Cultural Heritage Working Committee Luo Zhewen, Meng Fanxing A Tang Dynasty wall painting on the girdle of the Buddha's throne in the center of the door panel was found to be inscribed.
1973	Central and local heritage practitioners	Qi Yingtao, Luo Zhewen et al. Not available.
2004	Shanxi Institute of Ancient Building Conservation	Qiao Yunfei, Shi Guoliang, Chang Yaping et al. Photographs, mapping drawings, survey reports, restoration designs.
2005	Taiyuan Huanzhong Geotechnical Survey.	Qin Jinsheng et al. Report on the Geological Survey of the Foguang Temple.
2006	Institute of Architectural Design and Research, Tsinghua University; Institute of Cultural Heritage Protection, Tsinghua Institute of Urban Planning and Design, Beijing	Liu Chang, Wei Qing, Zhang Rong et al. The Foguang Temple Survey Study Report; The Foguang Temple Conservation Plan.

Figure 7.24: The timeline of the restoration process of the East Hall

110 An ink inscription beneath the main purlin on the north side reads: "Donor, the late Right Army Lieutenant Wang, and the temple sponsor, the Buddhist laywoman Ning Gongyu from the capital." This inscription corresponds with the stone sutra pillar standing in front of the hall, and together they provide the key evidence confirming that the East Hall was constructed during the Tang dynasty.

However, as shown in the figure 7.24, which summarizes the investigations carried out since its rediscovery, China did not undertake any restoration work at Foguang Temple; efforts focused primarily on documentation and survey activities rather than intervention.[111]

According to the available sources, because no formal restoration has been carried out at Foguang Temple, there is no complete structural analysis or diagnostic report. However, existing records indicate that the building itself has long exhibited a series of problems.

Figure 7.25: The front view of the East Hall

7.2.3 Logic of the Intervention Strategy

To date, no restoration has been carried out on the East Main Hall of Foguang Temple. The current conservation philosophy in China holds that intervention has a profound impact on the authenticity and integrity of cultural heritage, and that

[111] Tsinghua University Architectural Design and Research Institute, Beijing Tsinghua Institute of Urban Planning and Design, Institute of Cultural Heritage Conservation. Report on the Architectural Survey of the East Main Hall of Foguang Temple; Antiquities Press: Beijing, China, 2011. (In Chinese)

inappropriate restoration may cause irreversible damage. Based on the structural and spatial analysis presented in the previous section, Foguang Temple is not merely a Tang-dynasty religious building, but also a living record for the study of ancient spatial design and ritual order. Blind restoration, the addition of structural elements solely to enhance stability, or large-scale dismantling and rebuilding would all affect historical stratification and spatial order.

For this reason, the adopted conservation strategy is to "maintain the existing condition through minimal intervention," rather than to "optimize the structure through engineering logic." Through increasingly refined investigation and monitoring, data on Foguang Temple continue to be accumulated, providing the basis for formulating a well-founded and appropriate conservation plan in the future.

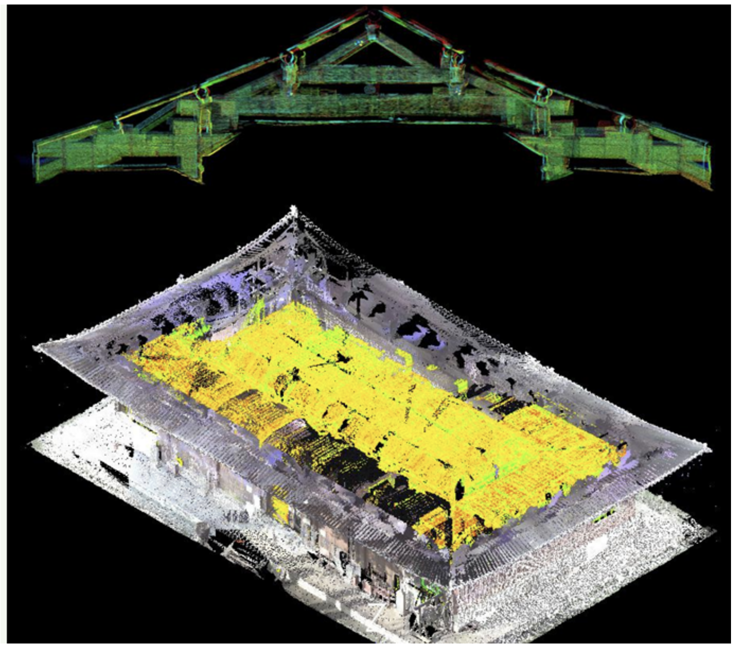


Figure 7.26: 3D laser scannin

In the early decades, scholars such as Liang Sicheng actively conducted surveys and re-surveys of Foguang Temple. Since 2005, documentation has entered the digital era. Between 2005 and 2011, investigations and measurements relied primarily on comprehensive 3D laser scanning, supplemented by total-station surveying and manual measurements for specific areas, in order to record the current condition of the East

Hall's timber structure (Figure 7.26).

From 2014 to 2018, conservation work focused on oblique photogrammetry using drones, 3D laser scanning surveys, orthophoto imaging, and laboratory sampling and analysis. In recent years, micro-environmental meteorological monitoring has been introduced, along with the installation of permanent observation markers, periodic comparisons of 3D laser-scanning data, and displacement-monitoring analysis (Figure 7.27).

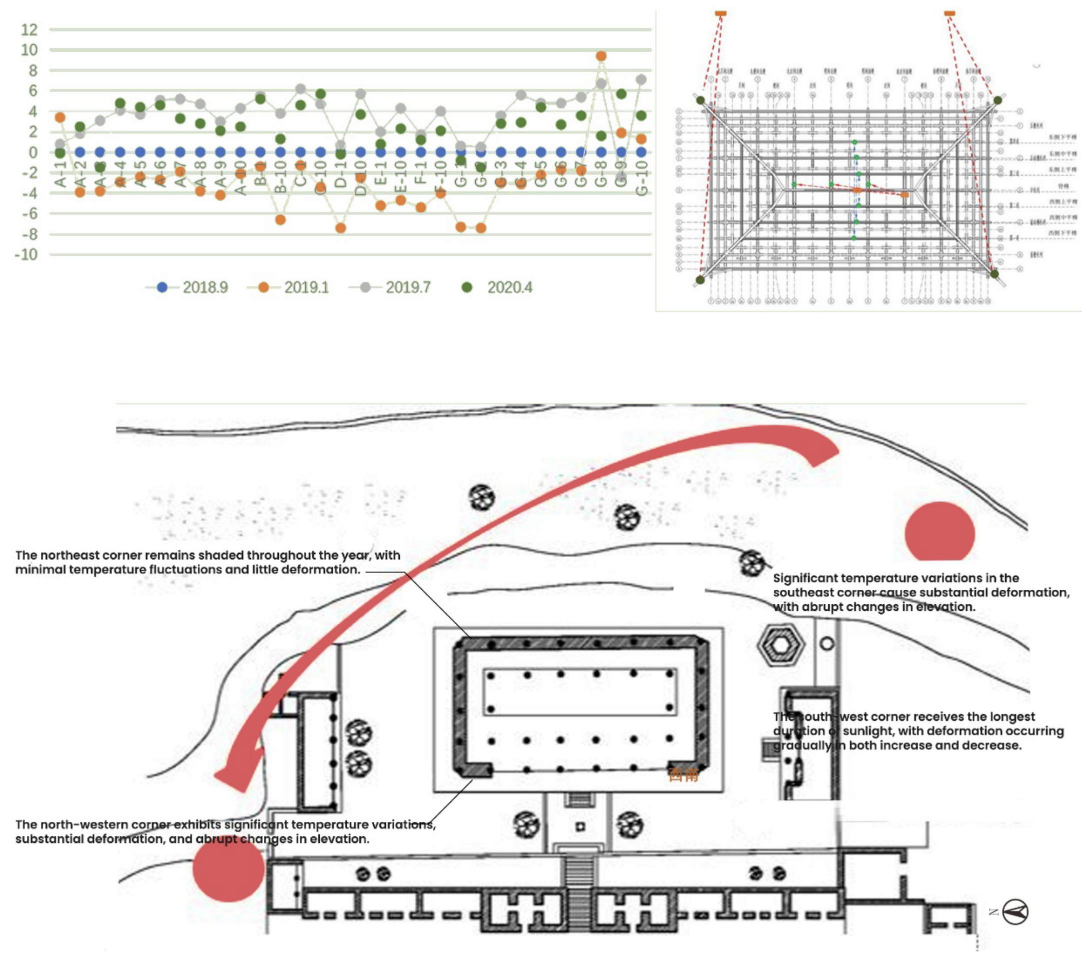


Figure 7.27: Study on Micro-Displacement of the Wooden Structure in the East Hall of Foguang Temple

However, in 2015, media reports surfaced stating that "timber components of the East Hall at Foguang Temple have developed cracks, deformation, and twisting, requiring temporary scaffolding for support, and water stains are visible on the walls." As part of the Wutai Mountain World Cultural Heritage site, the East Hall—being the largest and best-preserved surviving Tang-dynasty timber structure in China—is of exceptional significance. Yet as early as the 1950s, signs of subsidence had already appeared at the northeast corner of the hall.

By August 2017, the situation had worsened, with serious water leakage both inside and outside the building. Staff at Foguang Temple were forced to cover the Luohan statues with plastic sheets to keep out the rain. Only temporary measures, such as repointing the roof tiles, were undertaken to alleviate the leakage in the short term.

Figure 7.28： The left side shows a temporary timber support frame installed to prevent further settlement at the northeast corner of the roof. The right side shows plastic sheeting used as a temporary covering to protect the sculptures from rainwater leakage.

At present, many researchers—including academic institutions—have conducted technical monitoring and have begun constructing digital databases for Foguang Temple. However, the fundamental structural problems remain unresolved. According to officials from the Shanxi Provincial Cultural Heritage Administration, "the restoration plan for the East Hall of Foguang Temple is still under study. The proposed plan has been submitted to the National Cultural Heritage Administration and is awaiting approval. The specific timeline and methods for restoration have not yet been determined, so it is too early to discuss repair works." Similarly, the restoration plan for the Liao-dynasty Yingxian Timber Pagoda underwent hundreds of revisions and over twenty years of expert debate before any intervention could be taken.[112]

7.2.4 Critical Reflection

Foguang Temple is not an ideal "restoration case" among the four case studies. In contemporary practice, the East Main Hall of Foguang Temple has long been managed mainly through monitoring and routine maintenance, while major restoration has been avoided. To some extent, this strategy can be seen as an adoption and localized response to the Western principle of "minimal intervention." However, minimal intervention does not mean taking as little action as possible. Blind intervention may produce an incorrect historical stratification, while prolonged inaction may accelerate structural deterioration. This dilemma reflects the practical challenges of timber conservation.

At present, the increasingly detailed structural monitoring carried out at Foguang Temple provides a strong basis for conservation decision-making. In timber structural systems that carry long-term loads and are continuously affected by environmental conditions, deformation and hidden defects tend to develop in a progressive and cumulative manner.

Therefore, compared with the Main Hall of Nanchan Temple—characterized by dismantling and reconstruction and an orientation toward hypothetical restoration, with an emphasis on rebuilding form and constructional order—the East Main Hall of Foguang Temple represents a different authenticity approach and its boundaries. Under a highly intact historical condition, the use of modern techniques to examine and

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[112] Jing, Wang, and Masui, "Analysis for Conservation of the Timber-Framed Architectural Heritage in China and Japan from the Viewpoint of Authenticity," 9.

document structural behavior is a sound starting point.

At the same time, it also suggests that, for major historic timber buildings—especially those of great age and rich historical information—clear and systematic investigation is a necessary prerequisite. For timber buildings that remain in relatively good structural condition, early risk monitoring and preventive measures are equally essential.

Conclusion

This part, through a comparison of four case studies, demonstrates that authenticity in the conservation of historic timber structures is not a single objective, but a decision-making framework that continuously negotiates between structural safety, the preservation of historical evidence, and the continuity of construction order. In timber structural systems in particular, the replaceability of components, the reconfiguration of joints, and the possibility of altering structural working mechanisms inevitably expand authenticity beyond the question of "how much original material is preserved. Instead, authenticity becomes a comprehensive judgment involving structural stability, the legibility of construction logic, and the proportional and spatial order embedded in the original structure.

In the Italian context, whether timber structures require reinforcement or reconstruction due to poor management, fire, or other causes, contemporary conservation choices did not emerge fully formed. Historically, timber buildings often underwent temporary shoring, partial dismantling, or reconstruction. When addressing such conditions today, Italian conservation teams neither fully dismantle buildings to restore a single historical phase nor entirely reject earlier reinforcement measures. Instead, they consistently adopt a structural perspective, focusing on stabilizing load paths and improving joint performance. When new structural systems or materials are introduced, they are typically applied in a stratified manner so that each historical layer remains clearly identifiable. Overall, Italian timber conservation prioritizes structural compatibility and the continuity of load paths, rather than stylistic or antiquarian reconstruction.

From the perspective of materials used in conservation, material retention is not treated as an absolute requirement. Instead, priority is given to maintaining the original structural concept and static system. Provided that modern safety standards are met, the original structural form and historical value of the building should be preserved as much as possible. The reinforcement of individual components is considered acceptable if it does not alter the overall structural working mechanism. Regarding component replacement, conservation practice has evolved from the uncritical use of new materials such as concrete toward a greater emphasis on material compatibility, with the aim of achieving structural stability after intervention.

In contrast, conservation practice in China further broadens the scope of authenticity in timber architecture. Beyond structural and technical considerations, spatial order, proportional systems, and the historical and cultural meanings embedded in the structure are also treated as critical factors influencing intervention. The conservation path represented by the Main Hall of Nanchan Temple reflects a form of selective reconstruction oriented toward the re-presentation of constructional order and architectural form. When authenticity is understood in terms of Tang-dynasty proportions, modular systems, and construction logic, conservation may seek to correct and reconstruct order through dismantling and reconstruction and hypothetical restoration. However, this approach inevitably confronts issues concerning the selection of historical layers and the limits of available evidence.

In contrast, the East Main Hall of Foguang Temple represents a highly cautious approach. When material authenticity and historical integrity are given priority, conservation strategies tend to emphasize monitoring and maintenance while postponing large-scale intervention. At the same time, this case highlights that minimal intervention is not equivalent to taking as little action as possible. In the absence of clear thresholds and a transparent decision-making framework, excessive delay may exacerbate progressive deformation and the accumulation of hidden damage, thereby transferring risk into the future and potentially necessitating more irreversible intervention.

A review of these four cases that both Italy and China finds their structural systems, conservation techniques, and philosophies influencing final decisions. Meantime, they share a common challenge: how to preserve historical timber structures without transforming them into new engineering constructs, nor turning them into untouchable museum relics. The aim is to maintain their capacity to function as structural systems while respecting historical evidence. Consequently, this thesis's reinterpretation of authenticity can be further clarified: authenticity in timber restoration concerns not merely material survival, but also the continuity of structural mechanisms, the legibility of constructional order, the recognizability and reversibility of interventions, and prudent decision-making underpinned by diagnosis-monitoring-threshold principles. It is within this framework that the four case studies cease to be merely a collation of technical approaches, instead collectively constituting a comparative response to how ‘authenticity in timber structures’ is translated into structural strategies within contemporary restoration practice.

Chapter 8 Conclusion

This thesis adopts a comparative analysis of Italian timber roof structures and Chinese timber-framed systems to clarify the boundaries of authenticity theory in the conservation of timber heritage. It argues that authenticity standards derived from stone-based cultures and centered on material continuity are insufficient to address the key issues of timber conservation. The structural logic, constructional order, and craft systems of timber architecture are not only essential carriers of heritage value, but also the fundamental drivers that require the concept of authenticity to be reinterpreted within a timber context.

Part One traces the formation, institutionalization, and theoretical expansion of the concept of authenticity, revealing its philosophical roots in the European tradition of stone and brick construction. This tradition emphasizes material durability, formal stability, and the legibility of historical traces. However, when this stone-centered value system is directly applied to architectural traditions dominated by timber structures, authenticity can no longer be confined to original material alone but must be understood as structural authenticity. Whether through the theoretical evolution of Italian scholars from Brandi to Carbonara, Marconi, and Tamburini, or China's indigenous exploration from ‘restoring old as old’ to ‘authenticity (yuanzhenxing)’, both nations demonstrate an active reinterpretation of authenticity: it is no longer a singular value but a dynamic principle continually negotiated between cultural logic, material systems, and restoration practices.

Part Two compares the differences between the Chinese and Italian timber systems through an analysis of structural logic and joint construction. While the two traditions differ significantly in mechanical behavior, both demonstrate that structural diagnosis is a critical step linking conservation theory to actual practice. The feasibility and constraints imposed by structural logic determine whether conservation concepts can be implemented and how intervention strategies are shaped. Timber roof systems not only carry physical loads, but also embody refined craftsmanship, cultural symbolism, and aesthetic values. Their connection methods, renewal mechanisms, and construction logic define both the possibilities and the limits of conservation. In this sense, philosophical principles do not unilaterally dictate technical solutions; rather, they are negotiated through the interaction between structural feasibility and cultural orientation.

Part Three illustrates through four representative restoration cases how structural logic influences the manifestation of authenticity in practice. Italy's Palazzo Angelini and Villabruna prioritize minimal intervention, reversible reinforcement, and static equilibrium, emphasizing the preservation of original components and their inherent mechanical behavior. China's Nanchan Temple and Foguang Temple East Hall exemplify a shift from experiential reconstruction towards scientifically grounded restoration grounded in historical documentation and craft traditions. Despite differing restoration approaches and cultural logics, both reveal that timber authenticity cannot be defined solely by ‘raw materials’ but require balancing structural rationality, craft systems, historical information, and cultural continuity.

Based on the overall analysis, this thesis reaches the following core conclusions.

First, authenticity cannot be measured solely by the degree of material preservation. The lifecycle of timber architecture is inherently based on renewal, replacement, and regeneration. Authenticity should therefore be redefined as a comprehensive judgment grounded in structural logic, craft continuity, and cultural context.

Second, authenticity is a dynamic and multidimensional concept. Its meaning varies with different material systems and cannot be imposed through a single, universal standard. Timber construction compels us to move beyond a material-centered notion of authenticity toward a holistic understanding that integrates structural behavior, historical logic, and cultural continuity.

Third, the comparison of China and Italy provides important reference points for international timber heritage conservation. The experiences of both countries show that authenticity should be understood as a form of practical wisdom, dynamically negotiated among structural rationality, historical truth, and cultural continuity, rather than as a fixed set of technical rules.

In summary, this thesis contends that timber structure conservation should advance the concept of authenticity from ‘material preservation’ towards a framework of ‘structural-craft-cultural continuity.’ Only through profound recognition of timber architecture's dynamic vitality and cultural structural logic can conservation practices emerge that satisfy both ethical principles and technical requirements, ensuring buildings retain not merely their history but their living essence.

Glossary

Capriata: Truss
Capriata semplice: Simple truss
Capriata semplice con monaco: King post truss
Capriata semplice con saette: King post truss with braces
Capriata composta: Queen post truss
Capriata composta alla Palladiana: Queen post truss with braces
Capriata con nodo chiuso: Closed-joint truss
Capriata con nodo aperto: Open-joint truss
Catena: Tie beam
Monaco: King post
Colmo: Ridge beam

材份制（Cái fèn zhì）: A proportional modular system regulating the dimensions of timber components in traditional Chinese architecture.
营造法式（Yíngzào Fǎshì）: The Song-dynasty architectural manual establishing construction standards and modular rules.
斗拱（Dǒugǒng）: Bracket set. A system of interlocking wooden brackets transferring loads from roof to columns.
铺作（Pūzuò）: A specific compositional unit within the dougong system.
穿斗式（Chuāndòu shì）: Column-and-tie system
抬梁式（Táiliáng shì）: Post-and-lintel system
叉手（Chāshǒu）: Inclined strut (Chinese roof "truss-like" member)
蜀柱（Shǔzhù）: Vertical post in roof frame
举折（Jǔzhé）: Folded roof profile. The stepped inclination of roof slopes creating curvature in Chinese roofs.
升起（Shēngqǐ）: Column height increment
侧脚（Cèjiǎo）: Inclination of corner columns
榫卯（Sǔn–mǎo）: Mortise-and-tenon joint
桁（Héng）: Beam / Truss-like member

Chronology: Chinese Dynasties and Western Periods

Chinese Historical Period	Time Span	Western Historical Period	Time Span
Qin Dynasty	221 BCE–206 BCE	Late Classical Greece	5th c. BCE–146 BCE
Han Dynasty (Western and Eastern)	206 BCE–220	Roman Republic and Early Roman Empire	146 BCE–476
Wei, Jin, Northern and Southern Dynasties	220–589	Late Roman Empire / Fall of Western Rome	3rd–5th
Sui Dynasty	581–618	Early Middle Ages	5th–10th
Tang Dynasty	618–907	High Middle Ages	10th–13th
Song Dynasty (Northern and Southern)	960–1279	Late Middle Ages	13th–14th
Yuan Dynasty	1271–1368	Early Renaissance	14th–16th
Ming Dynasty	1368–1644	High Renaissance to Baroque	16th–17th
Qing Dynasty	1644–1911	Enlightenment to Industrial Era	17th–19th
Republic of China	1912–1949	Modern Era (World Wars)	Early 20th
People’s Republic of China	1949–present	Contemporary Era (Post-WWII to Present)	1945 – present

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Figure 6.8: Section of the timber roof truss A、B、C redrawn by the author. The data based on Gennaro Tampone, “Palazzo Angelini—Ripatransone, Ascoli Piceno,” in *Trattato sul Consolidamento*, 401, fig.12-17.

Figure 6.9: Section of the timber roof truss C drawn by the author.

Figure 6.10: Section of the trusses A and B after restoration drawn by the author.

Figure 6.11: Section of the trusses C after restoration drawn by the author.

Figure 6.12: Plan of the attic level after restoration redrawn by the author. The data based on Gennaro Tampone, “Palazzo Angelini—Ripatransone, Ascoli Piceno,” in *Trattato sul Consolidamento*, 401, fig.18.

Figure 6.15: Location of Palazzo di Villabruna drawn by the author.

Figure 6.17: Plan and sections of the roof before restoration drawn by the author.

Figure 6.18: Timeline of transformations and interventions on the roof structure drawn by the author. The data based on Francesco Doglioni, “Palazzo di Villabruna – Feltre, Belluno,” in Trattato sul consolidamento, 2nd ed., ed. Laura Bussi (Rome: Mancosu Editore, 2004), 272.

Figure 6.20: Section of the roof before restoration. The data based on Francesco Doglioni, “Palazzo di Villabruna – Feltre, Belluno,” in Trattato sul consolidamento, 2nd ed., ed. Laura Bussi (Rome: Mancosu Editore, 2004), 272, fig. 35-38.

Figure 6.21: Axonometric view of the roof and damage analysis drawn by the author.

Figure 6.22: Section of the roof after restoration drawn by the author.

Figure 6.25: Axonometric view of the roof after restoration drawn by the author.

Figure 7.1: Location of Nanchan Temple drawn by the author.

Figure 7.2: The plane of Nanchan Temple drawn by the author.
Figure 7.3: The plane of the Main Hall of Nanchan Temple drawn by the author.

Figure 7.4: The plane of the roof structure drawn by the author.

Figure 7.5: The timeline of the restoration process of the Main Hall of Nanchan Temple drawn by the author.

Figure 7.7: The front view of the Main Hall of Nanchan Temple before restoration drawn by the author.

Figure 7.8: The cross-section a-a of the Main Hall of Nanchan Temple before restoration. The data based on Zhang Rong, Wang Yizhen, Wang Qi, and Li Yumin, "Historical Context of Reconstruction, Modular Design System, and Statue Arrangement of Nanchansi Main Hall," Journal of Architectural History 3, no. 2 (2022): fig. 19.

Figure 7.9: Composition and cracking of the gable-side Chinese bracket before restoration drawn by the author.

Figure 7.13: The cross-section a-a of the Main Hall of Nanchan Temple after restoration drawn by the author.

Figure 7.16: The gable-side Chinese bracket after restoration drawn by the author.

Figure 7.17: Axonometric view of the main hall of Nanchan Temple after restoration. Drawing by the author, based on Qianlang Li, Through Walls and Seeing Structures: Sectional Studies of Classical Chinese Architecture (Nanning: Guangxi Normal University Press, 2009).

Figure 7.19: Location of Foguang Temple drawn by the author.

Figure7.20: Plane of the Foguang Temple. Redrawn by the author based on data from: Zhang Rong, Digital Survey Analysis of the East Hall of Foguang Temple and the Study of Tang-Dynasty Modular Construction, slide/p. 14.

Figure 7.21: The plane of the East Hall drawn by the author.

Figure 7.22: The cross-section a-a of the East Hall. Redrawn by the author based on data from: Zhou mo: Tracing the Roots of Shanxi's Early Timber Architecture

Figure 7.23: The cross-section a-a of the East Hall. Drawing by the author, based on Qianlang Li, Through Walls and Seeing Structures: Sectional Studies of Classical Chinese Architecture (Nanning: Guangxi Normal University Press, 2009).

Figure 7.24: Songfeng Jing, Wei Wang, and Takeshi Masui, "Analysis for Conservation of the Timber-Framed Architectural Heritage in China and Japan from the Viewpoint of Authenticity," *Sustainability* 15, no. 1384 (2023): 9, Table 3.

To my supervisors, Prof. Tocci. Thank you for choosing me as your student. It was your guidance and influence that revealed to me the immense fascination of history and structure. Each time a problem was solved, I experienced tremendous fulfillment. I also extend my gratitude to all the professors who taught me over these two years. It was through your instruction that I learned to set aside anxiety and walk steadily along the path of studying heritage restoration.

To my parents, thank you for your extraordinary decision that granted me the opportunity to study abroad and profoundly shaped my life's trajectory. My deepest gratitude also goes to my grandmother. I know your unwavering support and love remain my greatest source of strength.

To my friend Anita, your presence, our conversations, and your help made this writing process feel less like solitude and more like a shared journey.

With this letter, I extend my heartfelt thanks to everyone who has enabled me to reach this point.

Yunting Li

Torino, 2026