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Study on Wooden Relics from the Perspective of Cultural Heritage Conservation: A Case Study of the Tianluoshan Site in the Hemudu Culture

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ABSTRACT : *This study focuses on the wooden relics from the Tianluoshan Site of Hemudu Culture (7,000–5,500 years ago), a well-preserved Neolithic village site in the lower Yangtze River basin, from the perspective of cultural heritage conservation. The site, excavated since 2004, has yielded abundant wooden remains—including stilt-style buildings, wooden stockade walls, single-log bridges, and unique butterfly-shaped artifacts—providing crucial material evidence for understanding Hemudu Culture's continuous development, prehistoric social life, and sun worship-related religious practices. The paper first analyzes the historical and cultural value of these relics, emphasizing their role in revealing ancient production/living scenarios and religious beliefs. It then identifies the primary threats to the wooden relics: physical damage, chemical corrosion, and biological erosion. Finally, the study proposes targeted conservation strategies. These approaches aim to protect the relics' original appearance while enhancing public access to this prehistoric cultural heritage.*

KEYWORDS - *Wooden Relics; Conservation; Tianluoshan Site; Hemudu Culture; Prehistoric Wooden Artifacts*

I. INTRODUCTION

As a vital component of ancient cultural remains, wooden relics encompass a wide range of objects, including wooden artworks such as sculptures and screens, as well as daily-use items like coffins and outer coffins, houses, and boats. These relics serve as witnesses to the vast course of human history, recording the vicissitudes of the world and enduring the changes of weather over thousands of years. Nevertheless, they ultimately succumb to the erosion of time. Over millennia, wooden relics have silently endured damage caused by physical weathering, chemical weathering, biological weathering, and even human-induced destruction. Among various cultural relics, wooden artifacts are more vulnerable to damage compared to stone, iron, and other types of relics, making them a key research focus in the field of cultural heritage conservation.

The Tianluoshan Site, dating back 7,000 to 5,500 years, is a village site of the Hemudu Culture that boasts the best above-ground environmental conditions and relatively intact underground remains discovered so far. Archaeological excavations at the site began in February 2004. Over the past 20 years of excavations, a large number of multi-layered wooden relics have been unearthed, including stilt-style buildings, wooden stockade walls, and single-log bridges. These findings demonstrate the continuous and basically stable development of the Hemudu Culture from its early to late stages. The existing excavation results have not only gained valuable time and scientific basis for the effective conservation of the site but also provided precious materials for promoting in-depth research on the Hemudu Culture, expanding its influence, and even advancing the long-term goal of applying for World Heritage status. An in-depth analysis of the wooden relics at the Tianluoshan Site to understand their current state, characteristics, and value not only reveals the social and historical information contained within these relics but also offers references for the conservation of wooden cultural artifacts.

II. HISTORICAL AND CULTURAL VALUE OF WOODEN RELICS AT THE TIANLUOSHAN SITE OF HEMUDU CULTURE

The Tianluoshan Site of Hemudu Culture, a pivotal archaeological discovery in the lower reaches of the Yangtze River, is firmly rooted in the Neolithic Age—a period marked by the rise of settled agriculture and early communal life in ancient China. Unlike many fragmented prehistoric sites in the region, Tianluoshan stands out for its relatively intact underground stratigraphy and well-preserved organic remains, making it an invaluable window into the Hemudu people's way of life. The wooden relics unearthed here are particularly remarkable, spanning a continuous time period of approximately 1,500 years, dating back from around 7,000 to 5,500 years ago. This long temporal span not only reflects the enduring presence of Hemudu cultural traditions at the site but also offers a rare opportunity to trace subtle changes in woodworking techniques, architectural styles, and daily practices across generations.

Among the most significant wooden finds are the structural remains of stilt-style wooden buildings, double-row-pile wooden stockade walls, and a river-spanning single-log bridge. These features collectively and clearly illustrate the core early village elements of the ancient Tianluoshan settlement within the Hemudu cultural context. The stilt-style buildings, elevated on wooden piles to adapt to the region's humid, waterlogged environment, reveal the Hemudu people's sophisticated understanding of local ecology and their ability to engineer structures that could withstand seasonal flooding. The double-row-pile stockade walls, meanwhile, suggest a concern for communal defense or spatial demarcation, hinting at the emergence of organized community management. The single-log bridge, carved from a single massive tree trunk and spanning a nearby waterway, further underscores the practical ingenuity of Hemudu woodworkers and the importance of waterways in facilitating transportation and daily activities within the village.

In addition to these architectural remains, a wealth of smaller wooden artifacts—including wooden oars (likely used for navigating the region's rivers and lakes), wooden plows (critical tools for early rice cultivation, a staple of Hemudu agriculture), smooth wooden sticks (possibly for digging or weaving), intricately crafted butterfly-shaped objects, simple wooden handles (for tools like axes or adzes), and thick wooden column pit pads (used to stabilize building columns)—vividly depict the diverse production and living scenarios of the ancient Hemudu people. These artifacts are not mere functional objects; they bear the marks of human hands, from the smooth polish of frequently used handles to the precise cuts of plow blades, offering tangible connections to the daily labor, subsistence activities, and even aesthetic preferences of the people who created them.

Among all these wooden artifacts, the butterfly-shaped objects are uniquely characteristic of the Hemudu Culture, distinguishing them from other contemporary Neolithic cultures in China. Primarily crafted from wood and ivory (materials that would have required careful selection and processing), with only a small number made of stone, these objects are notable for their symbolic rather than practical function. Wooden butterfly-shaped objects, in particular, are categorized into three distinct types based on their decorative motifs: symmetrical flying bird type, two birds facing each other type, and single bird standing sideways type. In prehistoric cultures worldwide, bird motifs often carry religious or ritual significance, and in the case of Hemudu, such artifacts typically reflect sun worship—a common belief system in early agricultural societies that linked the sun's movement to crop growth and survival.

Yet, despite their immense value, the wooden relics at the Tianluoshan Site have suffered varying degrees of damage, both during their long underground burial and after excavation. Before being unearthed, the relics were exposed to waterlogging, soil pressure, and slow microbial activity; after excavation, they faced rapid changes in humidity, temperature, and oxygen levels—all of which accelerate wood decay, cracking, and deformation. As cultural relics that carry irreplaceable historical information and profound cultural inheritance significance, the conservation of these wooden artifacts is not merely a technical task but an urgent issue that must be addressed in the field of cultural heritage conservation. Their protection is essential to ensuring that future generations can continue to study and learn from the rich cultural legacy of the Hemudu people.

III. Current Conservation Status of Wooden Relics at the Tianluoshan Site of Hemudu Culture

Wooden relics, invaluable carriers of historical and cultural heritage ranging from ancient shipwrecks to imperial coffins and ritual artifacts, are inherently composed of wood—a natural polymeric material whose structural integrity relies on three core components: cellulose, hemicellulose, and lignin. Cellulose, a linear polysaccharide accounting for 40–50% of wood's dry weight, forms the rigid skeletal framework; hemicellulose (20–30%), a branched polysaccharide, acts as a binding agent between cellulose and other components; and lignin (15–30%), a complex aromatic polymer, reinforces the cell walls and provides resistance to microbial attack. This intricate molecular structure, while robust in its natural state, becomes highly vulnerable over millennia of underground burial.

During thousands of years of interment in soil or aquatic environments, groundwater—often containing dissolved minerals like calcium, magnesium, and iron—permeates the porous structure of the wood. Cellulose, with its abundant hydroxyl (-OH) groups, exhibits strong hydrophilicity, enabling it to absorb water continuously over centuries. This prolonged hydration causes the cellulose fibers to swell, gradually displacing air within the wood's cellular cavities and leading to the formation of water-saturated wooden cultural relics. In such relics, the moisture content can exceed 200% of the wood's dry weight, leaving the material soft, fragile, and prone to collapse if mishandled.

Extensive wood science research and analytical techniques (e.g., nuclear magnetic resonance spectroscopy and thermogravimetric analysis) have identified three distinct types of water in these saturated relics, each with unique interactions with the wood matrix:

Bound water: Tightly bonded to cellulose and hemicellulose via hydrogen bonds, this water is integral to maintaining the polymers' structural stability and cannot be removed without altering the wood's molecular configuration.Free water: Also known as "capillary water," this water resides in the wood's large pores and cell lumens, unbound to organic components and free to flow under gravity or pressure.Adsorbed water: A thin layer of water molecules attached to the surface of wood fibers through physical adsorption, bridging the gap between bound and free water.

The behavior of these water types directly influences the relics' post-excavation stability. For slightly decayed wooden relics—where cellulose and lignin remain largely intact—the loss of free water (e.g., through natural evaporation) typically does not induce deformation, as the rigid cell structure retains its shape. However, in highly decayed relics, prolonged underground microbial activity or chemical erosion weakens the cellulose framework, breaking down long polymer chains into shorter fragments. When these fragile relics are unearthed and exposed to ambient air, free water evaporates rapidly, creating internal tension within the compromised cell walls. This tension leads to irreversible shrinkage: in severe cases, dimensional changes of up to 15% have been observed in ancient wooden beams. Worse, if the surrounding humidity fluctuates (e.g., due to seasonal weather changes or indoor climate variations), the wood enters a destructive dry-wet cycle. During each cycle, the relics swell as they reabsorb moisture and shrink as they dry, causing microcracks to form and propagate. Over time, these cracks widen, leading to warping, splitting, or complete fragmentation of the relic.

Beyond physical damage, chemical degradation poses another critical threat to wooden relics, primarily driven by two interconnected processes: oxidation and hydrolysis. Hydrolysis, the breakdown of polysaccharides by water molecules, is highly sensitive to pH levels. In acidic environments (e.g., soil with high concentrations of organic acids from decaying plant matter), cellulose and hemicellulose undergo hydrolysis to form short-chain sugars and organic acids, further lowering the pH and accelerating degradation. In alkaline environments (e.g., soil rich in carbonates), cellulose reacts with hydroxyl ions to form alkali cellulose—a brittle, water-soluble compound that dissolves gradually, leaving the wood structure porous and weak.

During long-term deep burial (typically >2 meters below the surface), the underground environment maintains relative stability: constant temperature (5–15°C), low oxygen levels, and buffered pH (usually 6.0–7.5 in neutral soils) minimize fluctuations that trigger hydrolysis or oxidation. As a result, chemical decay in deep-buried relics is relatively slow and localized. In contrast, wooden relics buried in shallow layers (≤1 meter deep) are far more vulnerable. Shallow soils are exposed to seasonal temperature changes, rainfall infiltration, and root activity—all of which disrupt pH balance. For example, in forested areas, decomposing leaf litter can lower soil pH to 4.0–5.0, creating an acidic environment that accelerates cellulose hydrolysis.

Additionally, if unearthed wooden components contain metal elements—such as iron nails in ancient furniture or copper fittings in shipwrecks—a third chemical process, electrochemical corrosion, may occur. In humid environments (relative humidity >60%), water acts as an electrolyte, creating a galvanic cell between the metal (anode) and the wood (cathode). This reaction releases metal ions (e.g., Fe^{2+}, Cu^{2+}) that diffuse into the wood, forming colored precipitates (e.g., iron oxides or copper hydroxides). These precipitates not only stain the wood (often appearing as reddish-brown or greenish spots) but also catalyze further oxidation of cellulose, exacerbating degradation.

The natural environment is teeming with microorganisms—including fungi, bacteria, and actinomycetes—that thrive on organic materials like wood, making biological erosion one of the most destructive threats to wooden relics. Among these microorganisms, fungi (particularly members of the phyla Basidiomycota and Ascomycota) are the primary decomposers. Unlike bacteria, which primarily break down simple sugars, fungi secrete powerful enzymes (e.g., cellulases, hemicellulases, and ligninases) that can degrade complex wood polymers. Notably, many wood-rotting fungi (such as Trametes versicolor and Aspergillus niger) have extremely low oxygen requirements—surviving on concentrations as low as 1–2%—and the small amounts of oxygen trapped in wood cavities are sufficient to sustain their growth.

As a result, wooden relics suffer severe microbial erosion both before and after excavation. Pre-excavation, fungi colonize the wood's interior, forming thread-like hyphae that spread through cell lumens and pits. These hyphae secrete enzymes that break down cellulose and lignin, converting wood into fungal biomass. Post-consumption, the fungi leave behind mold stains (ranging from black and green to red and yellow) and mycelial mats, which not only obscure the relic's original appearance but also weaken its structure—often making intricate carvings or inscriptions unrecognizable. Bacteria, though less destructive than fungi, contribute to secondary decay by fermenting the sugars released by fungal enzyme activity, producing acidic byproducts that further degrade the wood.

Post-excavation, biological threats extend beyond microorganisms to include macroorganisms. Small insects such as termites (e.g., Reticulitermes flavipes) and wood-boring beetles (e.g., Anobium punctatum) feed on cellulose-rich wood: termites hollow out the interior, leaving only a thin outer shell, while beetle larvae tunnel through the wood, creating small holes (known as "exit holes") as they mature. Larger animals, such as cattle, sheep, and rodents, pose risks to relics displayed in outdoor or semi-protected areas—cattle and sheep may rub against or gnaw on wooden structures, while rodents may nest in or chew through fragile relics.

The synergistic combination of physical, chemical, and biological damage accelerates the destruction of wooden relics at an alarming rate. A single highly decayed relic, if left unprotected, can disintegrate completely within 5–10 years of excavation. This urgency underscores the imperative to implement science-based conservation measures for existing wooden artifacts. Such measures may include controlled dehydration (e.g., using polyethylene glycol to replace water in saturated relics), pH stabilization (applying buffer solutions to neutralize acidic or alkaline conditions), antimicrobial treatments (using non-toxic fungicides to inhibit microbial growth), and environmental control (maintaining constant temperature and humidity in storage or exhibition spaces). Without these interventions, countless irreplaceable wooden relics—each holding unique insights into human history, technology, and culture—risk being lost forever.

IV. CONSERVATION OF WOODEN RELICS AT THE TIANLUOSHAN SITE OF HEMUDU CULTURE

Wooden heritage—encompassing ancient architectural components, ritual artifacts, and archaeological finds like sunken ship timbers—serves as an irreplaceable link to human history, craftsmanship, and cultural identity. Its conservation, however, is a delicate balancing act: it demands safeguarding the relics' physical integrity and original character while making them accessible to the public, as widespread interest and understanding are often the foundation of long-term conservation support. To achieve this balance, two core objectives must guide all efforts: protecting the authentic appearance and structure of wooden relics through science-based methods, and presenting them in engaging, accessible ways to foster public connection—ultimately creating a cycle where awareness fuels better conservation outcomes.

The first step in effective wooden heritage protection is to address the root causes of decay—primarily uncontrolled water absorption (which leads to swelling, shrinkage, and structural collapse) and microbial erosion (by fungi, bacteria, or insects that break down cellulose and lignin). Traditional dry conservation techniques, such as air-drying or chemical dehydration, often fail for highly degraded, water-saturated relics (e.g., wooden remains from underwater archaeological sites), as rapid moisture loss triggers irreversible cracking.

Even well-stabilized wooden relics often suffer from surface damage—including cracks, mold stains, peeling of original coatings, or small losses of material—due to centuries of burial or post-excavation exposure. Restoring these flaws requires strict adherence to the five fundamental principles of cultural heritage conservation, which ensure that repairs respect the relic's authenticity and do not compromise future research:

Principle of Preserving the Current State: Prioritizes stabilizing existing conditions over unnecessary restoration, avoiding changes to the relic's "historical patina" (e.g., natural discoloration from age). Principle of Restoring the Original State: Only repairs damage caused by decay or human error (not intentional historical modifications), using evidence (e.g., archaeological records, historical images) to guide accuracy. Reversibility Principle: All restoration materials (e.g., adhesives, fillers) must be removable in the future, allowing for new conservation techniques or discoveries to be applied without damaging the original wood. Identifiability Principle: Restored areas must be subtly distinguishable from the original relic (e.g., using a slightly different shade of filler) to avoid misleading viewers about the relic's true condition.Minimum Intervention Principle: Uses the least invasive techniques possible—for example, filling small cracks with microcrystalline wax (a reversible, low-toxicity material) instead of replacing entire wood fragments.

Guided by these principles, conservationists have developed a range of specialized materials tailored to wooden relics. For instance, mold stains (caused by fungal hyphae) are treated with bio-based fungicides derived from plant extracts (e.g., neem oil), which eliminate mold without bleaching the wood. For larger cracks, a mixture of cellulose powder (matched to the relic's wood type) and reversible acrylic adhesive is used to fill gaps, then sanded to match the surrounding surface texture. For relics with original painted decorations (e.g., ancient wooden statues), conservationists use micro-sampling and X-ray fluorescence (XRF) analysis to identify the original pigments, then recreate them using natural, light-stable materials (e.g., mineral-based paints) to restore faded colors. The goal is not to "perfect" the relic, but to present its most authentic form—allowing visitors to see both its historical beauty and the traces of time it carries.

While physical conservation and restoration protect wooden relics, they often limit public access—many fragile relics cannot be displayed in permanent exhibitions, and geographic barriers prevent global audiences from viewing them. Digital technology solves this dilemma by creating virtual replicas that preserve the relics' details while making them universally accessible, all without risking physical damage.

The process begins with high-precision data capture. Conservation teams use 3D laser scanning (with a resolution of up to 0.1 mm) to map the relic's entire surface, capturing even tiny cracks, tool marks, or decorative patterns. For relics with complex internal structures (e.g., hollowed-out wooden containers), computed tomography (CT) scanning is used to create cross-sectional images, revealing hidden features that would be impossible to see in physical form. These data sets are then processed into high-fidelity digital models using specialized software (e.g., MeshLab or Agisoft Metashape), which can be refined to remove minor scanning artifacts while preserving all original details.

To transform these models into engaging cultural resources, teams integrate historical and contextual information. For example, a digital model of an ancient wooden beam from a Song Dynasty temple might include interactive hotspots: clicking on a carved motif could pull up research on its symbolic meaning, while another hotspot might show how the beam fit into the temple's original architecture (using 3D reconstructions of the building). These digital models are then made available through online platforms—such as virtual museums, mobile apps, or VR experiences—allowing users to "handle" the relic (via touchscreens or VR controllers), zoom in on details, or explore it from angles impossible in a physical museum.

Beyond public access, digital models serve as permanent, disaster-proof archives. In the event of natural disasters (e.g., floods, fires) or accidental damage to the physical relic, the digital replica preserves its structural and aesthetic information, enabling future conservationists to study or even recreate it. It also supports global collaboration: researchers from different countries can analyze the same digital model remotely, sharing insights on wood types, craftsmanship, or decay mechanisms—accelerating progress in wooden heritage conservation.

The conservation of wooden heritage is not a single, static effort but a holistic strategy that combines scientific preservation, careful restoration, and innovative public engagement. The "wet conservation method" and aquarium-style museums address the relics' physical vulnerability; principle-guided restoration honors their authenticity; and digital technology breaks down barriers to access. Together, these approaches create a cycle where protection ensures the relics survive, accessibility fosters public care, and public support secures resources for future conservation. In this way, wooden heritage is not just preserved—it is brought to life, allowing current and future generations to connect with the stories, skills, and cultures it represents.

V. CONCLUSION

This study takes the wooden relics of the Tianluoshan Site—a well-preserved representative of the Hemudu Culture (7,000–5,500 years ago)—as the research object, systematically exploring their value, current conservation challenges, and targeted solutions from the perspective of cultural heritage conservation.

First, the analysis confirms the irreplaceable historical and cultural value of the Tianluoshan wooden relics. As material evidence of the Neolithic Age in the lower Yangtze River basin, these relics (including stilt-style buildings, wooden stockade walls, and unique butterfly-shaped artifacts) not only reveal the continuous development trajectory of the Hemudu Culture and the production-living patterns of ancient communities but also provide key insights into prehistoric religious practices such as sun worship, enriching the understanding of early Chinese civilization.

Second, the study identifies that the wooden relics face compound threats from physical, chemical, and biological factors. Physical damage caused by dry-wet cycles, chemical corrosion from oxidation/hydrolysis, and biological erosion by fungi or insects—exacerbated by post-excavation environmental changes—have become the primary obstacles to preserving these relics. This analysis clarifies the urgency and direction of conservation efforts.

Finally, the proposed conservation strategies—including the "wet conservation method" for water-saturated relics, surface repair adhering to heritage conservation principles (reversibility, minimum intervention, etc.), and digital preservation via 3D modeling—form a multi-dimensional protection framework. These approaches not only aim to maintain the original appearance of the wooden relics and slow down their degradation but also enhance public accessibility to this prehistoric heritage, laying a foundation for the long-term inheritance of Hemudu Culture.

In summary, the research on Tianluoshan's wooden relics not only provides a typical case for the conservation of water-saturated wooden artifacts in similar Neolithic sites but also emphasizes that cultural heritage protection should integrate scientific methods with cultural interpretation—ensuring that these "witnesses of history" continue to convey ancient civilizations to future generations.

REFERENCES

[1] X. Li, The Hemudu Culture: Archaeological Discoveries and Cultural Significance, Journal of East Asian Archaeology, 20(1-2), 2018, 45-68.

[2] J. Zhao, Z. Sun, and C. Li, Archaeological Excavations at the Tianluoshan Site (2004-2014): A Summary of Key Findings, Chinese Archaeology, 15(1), 2015, 78-92.

[3] H. Zhang, and Y. Wang, Conservation of Water-Saturated Wooden Relics: Challenges and Strategies, Studies in Conservation, 65(3), 2020, 189-205.

[4] Z. Wang, and J. Jiang, Prehistoric Sun Worship Reflected in Hemudu's Butterfly-Shaped Artifacts, Asian Perspectives, 58(2), 2019, 231-254.

[5] L. Chen, and M. Liu, Digital Preservation of Ancient Wooden Relics: Modeling and Cultural Interpretation, Digital Applications in Archaeology and Cultural Heritage, 28, 2022, 100456.

[6] B. Wang, C. Zhu, B. Wang, et al., Analysis of the biocorrosion community from ancient wooden constructions at Tianluoshan (7000–6300 cal BP), Zhejiang Province, China, Heritage Science, 12, 2024, 189.

[7] B. Wang, Y. Hu, B. Zhang, Y. Wang, X. Xie, K. Ye, Analysis of alterations and damages at the Neolithic earthen settlement and agricultural cultivation site in Tianluoshan, China, Archaeometry, 2025.