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WOOD AS A STRUCTURAL MATERIAL: CURRENT STATE OF THE ISSUE, PROBLEMS, PROSPECTS

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This document provides a systematic overview of the latest developments in the field of bendable and non-centrally compressed elements and composite elements made of wood and concrete, focusing on key topics including mechanical characteristics, molding processes, fire resistance, interfacial mechanisms and stability assessment. As a result of the analysis, it was determined that: glued wood, due to its multilayer structure, good flexibility and controlled surface behavior, has clear advantages when exposed to fire, bending and composite systems, although the stability of the surface at high temperatures and the mechanisms of prolonged aging require further study. Progress in the field of flexible wood components, driven by advances in hydrothermal softening, local compaction, material modification, and cross-sectional innovations, however, challenges remain related to molding stability and the continuity of the manufacturing process for large-sized parts. Wood–concrete composite structures exhibit excellent ductility, energy dissipation, and seismic performance, but uncertainty remains about the long-term durability of the joints and behavior under environmental conditions. In general, engineered wood materials are evolving from the study of individual properties to the development of a multiscale paradigm of "material-interface–structure–environment". Future work should strengthen the understanding of mechanics, multiscale modeling, process industrialization, and sustainability research to create high-performance wooden structural systems.

Keywords: *wood construction, wood–concrete composite structures, sustainability, compression, bending.*

Introduction. With the advent of low-carbon construction concepts and the growing demand for renewable materials, wood has once again attracted attention in the construction industry due to its light weight, high strength-to-weight ratio, renewability, and environmental benefits. In the field of engineering wood materials, the basis of research is the determination of structural strength in compression and bending. Currently, the wooden structures are based on elements made of solid and glued wood. Composite materials made of wood and concrete are a promising area. These systems are believed to have the potential to optimize structural performance, design flexibility, integrated load response, and stability. Research in the field of wood bending has made it possible to produce wooden parts of great curvature and arbitrary shape. Structures made of wood–concrete composites combine the light weight of wood and the high compressive strength of concrete, which demonstrates practical potential in seismic exploration and floor systems. Wood processing processes determine the stability of the components in case of fire and prolonged environmental exposure. Therefore, it is important to systematically analyze the progress of research on these categories of wood components.

Methods and materials. Bendable wooden elements. In recent years, researchers have pursued material modification, process innovation, and structural optimisation to improve the bending performance and reliability of solid-wood elements.

First, material softening and enhancement of plasticity form the foundation of solid-wood bending. For precious hardwoods such as teak, which are notoriously rigid and resistant to bending, researchers have proposed an innovative synergistic softening process. Research combining vacuum impregnation with softening solutions and saturated steam treatment significantly enhanced teak's plasticity, enabling successful bending processing [1]. This breakthrough overcomes the limitations of single-mode steam softening on hardwoods. Secondly, thermal modification – a common wood modification technique – exerts complex effects on bending properties. Kubojima, et al. [2] revealed a dual effect of heat treatment on wood toughness: in the early stage of treatment, the elastic modulus and bending strength may increase, but with prolonged treatment, the viscous and plastic components decline significantly, leading to increased brittleness and a continuous reduction in rupture work [2]. Thus, while moderate heat treatment can optimise certain mechanical indicators, excessive thermal modification severely impairs the wood's capacity for plastic deformation and undermines the toughness of bent elements – particularly under impact loading. Thirdly, enhancing density through compression densification constitutes a direct physical approach to improving mechanical properties, including bending performance. Li [3] compared different compression patterns and found that surface-compressed timber achieves the highest surface layer density, elastic modulus, and static bending modulus at equivalent overall compression ratios. For bent solid elements, this is instructive: selectively reinforcing the layer of a component that sustains the maximum bending stress most effectively increases flexural capacity and promotes material-efficient design, rather than applying uniform, whole-section compression [3].

Although Bal [4] did not directly investigate the bending process, the study demonstrated that impact bending strength exhibits a parabolic variation with span length. This underscores the critical influence of test system geometry and boundary conditions on the measurement of wood toughness [4]. When designing and testing bent solid elements, the support span encountered in service must be accounted for to ensure bending performance assessments are accurate and applicable. Node optimisation is crucial for maintaining the structural integrity of curved members. While Ribeiro AB. [5] focused on research into load-bearing timber structural joints, employing finite element modelling and parametric optimisation methods. This provides methodological guidance for node design in curved solid members. Such analysis can determine optimal mortise and tenon dimensions, minimising wood fibre cutting and damage whilst maintaining strength [5].

Consequently, research into curved solid timber members is inherently interdisciplinary–encompassing materials science, manufacturing processes, mechanics, and design. Current trends indicate that advancement in this field hinges upon: (1) innovative softening techniques to enhance wood plasticity; (2) targeted surface densification to optimise performance distribution; and (3) the application of advanced numerical tools for precise joint design. Future work should further elucidate the mechanisms underlying softening across species and develop more efficient, environmentally benign shaping and setting techniques to broaden the applications of solid-wood bending in architecture and furniture design. Presently the field faces three major challenges: (1) poor plasticity of hard species (e.g., teak) and the limited effect of traditional softening methods; (2) strength gains from heat treatment and densification often come at the cost of reduced toughness and ductility, increasing brittleness; and (3) a weak theoretical basis for node design, where stress concentrations readily trigger structural failure and systematic optimisation methods remain insufficient.

In recent years, numerous experimental and theoretical studies have focused on the flexural behavior of glued-laminated beams with varying cross-sectional geometries, species combinations, and reinforcement strategies, providing systematic evidence for their application in building structures, bridges, and long-span roofs.

Research into fundamental mechanical properties has established the theoretical basis for understanding the bending behaviour of glued laminated timber. Researchers systematically measured the material properties and flexural performance of glued laminated beams, revealing that engineered timber beams exhibit significantly higher strength and stiffness than conventional sawn timber, with strength increases ranging from 39% to 90% and stiffness improvements from 35% to 45% [6]. In terms of cross-section and structural innovation, multiple studies have highlighted the significant advantages of glued laminated timber as a bendable structural component, offering both manufacturability and plasticity [7; 8]. Some scholars demonstrate that both orthogonal and parallel T-configurations maintain high load-bearing capacity while reducing material consumption; orthogonal T-beams exhibit approximately 33% greater load-bearing capacity than rectangular beams [7]. A separate study on hollow laminated timber beams aimed to achieve weight reduction while controlling flexural deformation. This research demonstrated that carefully designed hollow cross-sections could reduce self-weight without compromising load-bearing capacity, thereby enhancing overall component efficiency while maintaining flexural performance [9]. The selection of timber species and laminated configurations exerts a significant influence upon the bending properties and mechanical response of glued laminated timber. Comparative studies integrating analytical models, finite element analysis, and experimental data from multiple timber species demonstrate a high degree of consistency among the three methodologies – with most discrepancies falling within ≤5% – validating the models' reliability in simulating bending behaviour [10]. This evidence supports the adaptability of glulam across diverse forestry regions and drives the development of new species for flexible timber components. Within reinforcement applications, steel plate reinforcement offers an alternative to FRP and CFRP [11]. While steel plates substantially enhance bending stiffness and load-bearing capacity, practical implementation requires balancing weight considerations against durability. Glulam exhibits predictable charring rates; strategically configured fire-retardant boards, thermal insulation layers, or thickened protective systems can substantially delay charring progression and extend fire resistance duration [12]. This research highlights the correlation between load-bearing capacity loss and effective cross-sectional reduction, proposing fire protection design methodologies based on char layer evolution patterns [12]. It provides scientific foundations for fire protection design, performance assessment, and code development in glulam structures.

Because glulam components offer high designability, controllable material properties, and flexural performance that can be markedly enhanced by section optimization and composite reinforcement, they represent one of the most promising forms within the bendable wooden elements system. Nevertheless, systematic quantification of how bending performance is affected by species-specific defects, interlayer interface behaviour, and long-term actions is still lacking; post-reinforcement interface bond-degradation mechanisms remain unclear; and stress models for hollow and complex sections are not yet complete. Future research should integrate advanced numerical modelling, interface bond characterisation, long-term performance, and fatigue studies to promote deep application of glulam in bendable members, curved beams, and large-span timber structures.

Compressed-Bendable wooden elements. Solid wood subjected to non-centrally compressed bending undergoes combined bending, localized compression, and shear. Existing studies provide relatively systematic evidence on the mechanical behavior of solid wood during compressed-bending processes.

First, the fundamental mechanical properties of wood constitute the basis for designing compressed-bending elements. Cao H. [13] systematically tested the density, moisture content, tensile, compressive, and shear strengths of engineered wood, confirming that wood exhibits linear elasticity in tension along the grain but elastoplastic behavior in compression, while its shear strength is substantially lower than its tensile and compressive strengths parallel to the grain. This implies that, in bending scenarios involving non-central compression, high shear concentrations should be avoided to prevent localized failure, which provides direct guidance for jig design and load-path planning [13]. Second, the enhancement of wood plasticity and its ability to retain permanent deformation are fundamentally controlled by its microstructural components. Zhang Y., et al. [14] noted that hemicellulose hydration, lignin thermal softening, and relative slippage between the crystalline and amorphous regions of cellulose constitute the core mechanisms governing longitudinal compression and permanent deformation (PDR). For compressed bending under noncentral loading, these micromechanisms determine both the magnitude of springback and the stability of the formed shape, providing the essential scientific basis for improving bending quality [14]. Third, hygrothermal conditions significantly alter the bending behavior of solid wood. Bending tests by Li and Zhao [15] demonstrated that water saturation and elevated temperature reduce MOE and MOR to approximately half of the air-dried values, while markedly increasing failure strain and toughness. This indicates that hygrothermal treatment can effectively enhance the plasticity required for compressed-bending elements, allowing larger curvatures without inducing brittle failure, thereby making it one of the most practical approaches for achieving non-centrally compressed forming [15]. In addition, the review by Wu, et al. [16] systematically compared softening methods such as boiling, steam, hot water, ammonia treatment, and microwaves, and noted that although each technique has specific advantages in improving plasticity, reducing cracking, and stabilizing the formed shape, a balance must be struck among mechanical performance, environmental impact, and industrial feasibility. This indicates that the selection of compression bending processes should be based on a comprehensive assessment of softening mechanisms, forming quality, and process continuity. Barnes, et al. [17] provided key engineering evidence. Their short-term steam heating of specimen centres at approximately 71°C did not significantly reduce the bending strength or compressive strength perpendicular to the grain of red oak and sweet maple (typically ≤10% reduction) [17]. It indicates that low-temperature steam can soften wood and enhance formability without substantially compromising structural performance, thereby validating its applicability for compressed-bending elements in industrial settings.

Overall, existing studies indicate that the plasticity and shape retention of solid wood under non-centrally compressed bending are jointly determined by hygrothermal conditions, microstructural changes, and intrinsic mechanical properties.

Within the research framework of compressed-bendable elements (non-centrally compressed), glued wooden elements have emerged as a crucial pathway for enhancing bendability and load-bearing performance due to their manufacturability, controllable layer configuration, and stable mechanical behavior. The mechanical properties and service reliability of such elements are jointly governed by layer composition, adhesive selection, manufacturing parameters, and the interface and charring behavior under fire conditions.

Layer configuration and adhesive performance are key factors influencing the compressive and bending capacities of glued wooden members. Experimental studies on mixed cross-laminated timber (CLT) conducted by Lee and Kim [18] show that using high-MOE species as the major layer significantly increases compressive strength, while phenol-resorcinol-formaldehyde (PRF) exhibits higher interfacial strength than the two polyurethanes, thereby reducing interface-dominated failure modes [18]. Similarly, Qian C. (2023 systematically reviewed manufacturing techniques for structural glued wood and pointed out that finger-jointing, wide-lamination, pressing parameters, moisture content, and adhesive curing behavior directly affect dimensional stability, strength uniformity, and subsequent bend-forming performance. Therefore, for compressed-bendable members, the configuration of the major load-bearing layers and the selection of thermally compatible adhesives form fundamental prerequisites [19]. Besides, numerous studies have indicated that the adhesive interface becomes a critical weak link under high-temperature or fire conditions. In CLT floor fire tests, Yang H., et al. [20] found that glue lines tended to crack first at elevated temperatures and evolve into fire-penetration paths. Consistently, Hu X., et al. [21] reported that the residual load-bearing capacity of glulam beams exposed to three-sided fire decreased markedly with prolonged exposure, and that fire-retardant treatment exerted a positive effect on interface integrity. Moreover, Zhang J., et al. [22] based on full-scale compartment fire tests coupled with a two-zone fire model, revealed the occurrence of randomized char-layer shedding during CLT combustion, which significantly alters heat release and temperature distribution and plays a crucial role in evaluating compression–bending behavior and residual strength. These findings collectively indicate that the reliability of glued wooden elements under combined compression and bending depends not only on material properties but also on the thermal stability of the adhesive interface. Furthermore, introducing densification or pre-compression techniques provides a viable route to enhancing the mechanical quality of wood substrates. Van Hai, et al. [23] demonstrated that bleaching and hot-pressing significantly improved the density, bending strength, and stiffness of compressed wood, offering higher-performance substrates for compressed-bendable glued elements. However, the permeability and interfacial compatibility of such densified materials with adhesives require further optimization to avoid insufficient bonding or brittle interfacial behavior.

In engineering practice, glued wooden components are often joined with connectors to form large-curvature or long-span elements. Wei X. and Guo W. [24] reported that although metal joints enable the assembly of curved laminated members, their in-plane and out-of-plane load-carrying capacities are lower than those of the members themselves, and they are prone to magnifying second-order effects. Thus, joint design must be incorporated into the overall stability evaluation. In addition, studies on flame-retardant film–scrimber composite systems have demonstrated synergistic effects between surface flame-retardant layers and treated cores, substantially reducing heat release rates and improving fire resistance, thereby providing safer composite strategies for indoor glued wooden elements [25].

In summary, existing research indicates that performance optimization of glued wooden elements within compressed-bendable systems should advance simultaneously across multiple dimensions, including layer configuration and adhesive selection, high-temperature interface stability, manufacturing consistency, and joint and flame-retardant composite design. These studies collectively provide essential theoretical foundations and engineering references for developing glued wooden components with greater bendability, enhanced fire resistance, and improved interfacial stability.

Wood-Concrete Elements. Wood–concrete composite elements combine the light weight and renewability of wood with the high compressive strength and durability of concrete, achieving a well-balanced compromise between structural performance and sustainability. Recent research has focused on three core issues: the mechanical behavior and seismic performance of composite material systems, interface connections and long-term durability, and numerical modeling and engineering applicability at the component and system scales.

Firstly, from the perspective of material modification and seismic performance of components, Dominguez-Santos, et al. [26] demonstrated that “wood-aggregate concrete blocks” prepared by adding wood-based additives (e.g., sawdust, wood chips) can reduce stiffness while significantly enhancing ductility when an appropriate dosage (≤15%) is used. This improvement measure enhances the energy dissipation capacity and seismic performance of reinforced concrete frames without significantly increasing costs. Researchers further indicate that this composite concrete holds potential for engineering applications in earthquake-prone regions and contributes to resource recycling [26]. Additionally, interface connection mechanisms and long-term performance are widely regarded as “critical controlling factors” for wood–concrete composites. Push-out tests by Wang, et al. [27] revealed pronounced differences in interface failure modes, load–slip behavior, and shear stiffness between bamboo–concrete and wood–concrete connections. These findings indicate that modified analytical models or material-specific design parameters are required to accurately predict shear resistance and slip behavior, underscoring that connection design cannot rely on empirical rules derived from a single material [27]. Meanwhile, long-term durability studies of adhesive-bonded joints by Giv, et al. [28] showed that wet-cast joints and ductile adhesives (e.g., PUR) generally outperform dry-cast joints and brittle epoxies under outdoor and combined environmental-load conditions. The results also indicate that interface properties may evolve significantly over time, suggesting that long-term environmental effects must be incorporated into design and maintenance strategies for engineering applications [28].

At the component and system levels, Pan, et al. [29] proposed and numerically validated a hybrid high-rise system that integrates lightweight timber modules with a reinforced-concrete core wall. In this system, every three stories are partially replaced by timber modules. Nonlinear time-history analyses revealed that reduced structural mass results in lower seismic demand, reflected in reduced base shear and interstory drifts [29]. These findings demonstrate that the proposed hybrid system not only complies with current regulatory requirements but also delivers seismic performance and carbon reduction benefits for high-rise buildings. In addition, stability studies on slab-type composite elements have provided new insights. Research on the axial-compression buckling behavior of NLT (nail-laminated timber) – concrete composite slabs by Gan, et al. [30] showed that in-plane axial compression induced by lateral actions can trigger plate-strip buckling due to low through-thickness stiffness. Experimental results and refined finite-element models incorporating initial buckling modes consistently revealed a characteristic two-span buckling pattern and associated failure mechanisms [30]. The study also provided ultimate axial capacities per unit width and displacement as well as moment–slip curves, offering direct experimental references for the buckling design of slab-type composite elements.

Current research on wood-concrete composite components has established three key consensus points. Firstly, moderate material blending and lightweight design can reduce seismic requirements and enhance ductility without compromising safety. Secondly, the type of interface connection and construction method directly determine both short-term mechanical performance and long-term durability, necessitating parameter calibration based on experimental data. Thirdly, integrating high-quality experimental data with calibrated numerical models is essential for engineering implementation and standardized design. Future work should emphasize multi-field coupled durability tests, standardization of connections, and life-cycle performance and carbon footprint assessments at larger structural scales, thereby promoting the industrialization and codification of wood–concrete hybrid structures.

Results and discussion. A holistic analysis of the literature shows substantive advances in enhancing engineered wood materials. However, several common principles and critical issues merit further investigation:

1. Micromechanical constraints on macroscopic performance remain prominent. Timber behavior during hydrothermal softening, densification, and bending is governed by cell-wall composition, moisture content, lignin softening, and cell-wall slippage. Existing studies clarify some micromechanisms, but a unified theoretical framework across species and processes is missing. This gap limits the predictive power of models and constrains performance-controlled design.

2. The glued interface is often the weak link in component reliability. The performance of glued timber under bending, compression, and fire conditions strongly depends on adhesive quality and interface stability. Studies indicate that adhesive layers tend to deteriorate preferentially at elevated temperatures, and char-layer shedding can further alter heat-transfer paths and stress distributions. Systematic data on interface aging and coupled environmental effects remain scarce, posing a challenge for the long-term reliability assessment of compressed and compressed–bendable components.

3. A gap exists between laboratory forming techniques and industrial implementation. Hydrothermal softening, localized densification, and various modification techniques have substantially improved the formability of bendable components, but most work remains at the laboratory scale. The forming stability, dimensional consistency, and process continuity for large-scale components have not been fully validated. Moreover, there is currently no unified assessment framework or systematic methodology to evaluate the cost-effectiveness and industrial viability of different softening technologies.

4. Interface behavior in composite systems remains highly complex. Wood–concrete composite structures show excellent load-bearing, slip, and energy-dissipation characteristics. But connection performance is highly sensitive to humidity, freeze–thaw cycles, fatigue, and long-term loading. Most existing models rely on short-term tests, which cannot accurately predict interface degradation or structural performance over a full service life.

5. Sustainability assessments require further systematization and regionalization. Environmental impact assessment studies, such as life cycle assessment research, have been conducted for glued and compressed wood products. However, differences in regional forestry resources, processing energy mixes, and climate conditions make it hard to apply current LCA data to different geographic contexts. Incomplete recycling pathways also prevent a full life-cycle closure of environmental impact assessments.

In summary, engineered wood materials are shifting from experience-driven practice to mechanism-driven, multiscale design and multi-material integration. This marks a major direction in structural engineering materials research.

Conclusion. Bendable wood structures, compressed–bendable elements, and wood–concrete composite structures constitute the core of contemporary engineered wood materials. They demonstrate broad application potential in terms of mechanical properties, formability, fire resistance, and sustainability. Analysis of existing literature indicates that techniques such as densification, laminate optimisation, hydrothermal softening, and localised reinforcement can significantly enhance wood's strength, plasticity, and durability. Adhesive systems and interface design play a critical role in structural reliability, and wood–concrete composite systems offer clear advantages for seismic resistance and component rehabilitation.

However, major gaps remain in micromechanical understanding, quantifying interfacial behavior, process validation for large-scale components, predicting long-term service performance, and regionally adapting environmental assessment. Future research should prioritize cross-scale testing, multi-material modeling, and full life-cycle analysis to create engineered wood materials that are high-performance, reliable, and sustainable.

Limitations and Future Directions. Although this review attempts to cover multiple research directions, several limitations should be acknowledged. First, heterogeneity among studies in tree species, experimental scale, process parameters, and environmental conditions constrains the direct comparability of results. Second, empirical data are insufficient for some critical mechanisms – such as adhesive aging, high-temperature interface behavior, and performance degradation under coupled hydrothermal conditions – limiting the precision of integrated conclusions. Third, the literature is dominated by laboratory-scale investigations, and systematic studies of industrial implementation remain scarce. Finally, the lack of standardized protocols for environmental impact assessment introduces uncertainty into sustainability evaluations of timber systems.

Future engineered wood research will explore multiscale mechanisms, interface-dominated performance, intelligent manufacturing, system-level integration, and sustainability. Advances in high-resolution imaging, digital modeling, intelligent manufacturing, and material modification will help timber systems move from single-property optimization to multifunctional, high-performance, whole-life design. This transition can make them a key enabler for green buildings and low-carbon infrastructure.

REFERENCES

1. Yao, L., Xu, M., Sun, D., & Wang, Z. (2024). Research on Teak Furniture Design and Node Optimization Based on Solid Wood Bending Technologv. *Furniture & Interior Design, 31*(08), 78–85. (In Chinese).
2. Kubojima, Y., Okano, T., & Ohta, M. (2000). Bending strength and toughness of heat-treated wood. *Journal of Wood Science, 46*(1), 8–15. DOI: 10.1007/BF00779547.
3. Li, R. (2025). Comparative study on overall, surface and centre compressed solid wood. *Scientific Reports, 15*(1). DOI: 10.1038/s41598-025-05827-y.
4. Bal, B.C. (2021). Effect of span length on the impact bending strength of poplar and pine woods. *BioResources, 16*(2), 4021–4026. DOI: 10.15376/biores.16.2.4021-4026.
5. Ribeiro, A.B. (2024). *Moment Resistant Joints for Timber Frames (PHD).* Coimbra: University of Coimbra.
6. Liu, W., & Yang, H. (2008). Experimental study on flexural behavior of engineered wood beams. *Journal of Building Structures, 29*(1), 90–95. (In Chinese).
7. Rao, Z., Wang, J., & Ning, F. (2020). Experimental study of negative bending performance of glulam T beam. *Journal of Central South University of Forestry &Technology, 40*(8), 155–163. (In Chinese).
8. Yao, T., Wang, J., Ning, F., & Rao, Z. (2019). Experimental research on flexural bearing capacity of larch glulam T-beam. *Journal of Central South University of Forestry &Technology, 39*(5), 124–131. (In Chinese).
9. Shang, P., Sun, Y.-F., Zhou, D., Qin, K.-R., & Yang, X. (2018). Experimental Study of The Bending Performance of Hollow Glulam Beams. *Wood and Fiber Science, 50*(1), 3–19. DOI: 10.22382/wfs-2018-002.
10. Kytka, T., Gašparík, M., Sahula, L., Novák, D., Karami, E., Das, S., & Sviták, M. (2024). Predicted and Experimental Bending Behaviour of Glulam Bonded by RPF Adhesive. *Materials, 17*(2). DOI: 10.3390/ma17020514.
11. He, M., Wang, Y., Li, Z., Zhou, L., Tong, Y., & Sun, X. (2022). An Experimental and Analytical Study on the Bending Performance of CFRP-Reinforced Glulam Beams. *Frontiers in Materials, 8*. DOI: 10.3389/fmats.2021.802249.
12. Korolchenko, D.A., & Portnov, F.A. (2024). Study on Structural Fire Protection and Fire Resistance of Glued Laminated Timber Columns. *Buildings, 14*(12). DOI: 10.3390/buildings14124049.
13. Cao, H. (2010). Study on Wood Properties of Citrus Japonica. *Journal of Huangshan University, 12*(5), 95–97. DOI: 10.3969/j.issn.1672-447X.2010.05.030. (In Chinese).
14. Zhang, Y., Song, K., & Tong, D. (2012). Mechanism of wood grain compression ratio and PDR influence. *Forestry machinery and woodworking equipment, 40*(11), 35–37.
15. Li, X., & Zhao, Y. (2024). Bending Performance of Water Saturated White Birch and Ash Wood at 20–100 °C. *Forests, 15*(7). DOI: 10.3390/f15071077.
16. Wu, Y., Zhu, J., Qi, Q., & Cui, L. (2022). Research progress of solid wood bending softening technology. Review. *Wood Research, 67*(6), 1056–1073. DOI: 10.37763/wr.1336-4561/67.6.10561073.

17. Barnes, H.M., Sanders, M.G., & Lindsey, G.B. (2014). Compression and bending strength of steamed, treated hardwoods. *BioResources, 9*(1), 537–544.
18. Lee, I.-H., & Kim, K.-H. (2021). Influence of adhesive and layer composition on compressive strength of mixed cross-laminated timber. *BioResources, 16*(4), 7461–7473.
19. Qian, C. (2023). Study on Manufacturing Technology of Structural Glulam. *Value Engineering*, 145–148. DOI: 10.3969/j.issn.1006-4311.2023.21.044. (In Chinese).
20. Yang, H., Wei, S., Shi, M., & Gao, B. (2023). Fire resistance test of glued wood floor in wooden structure building. *Building Structure, 53*(22), 134–139. DOI: 10.19701/j.jzjg.20210159. (In Chinese).
21. Hu, X., Chen, L., Xu, Q., Han, C., & Leng, Y. (2020). Experimental study of the mechanical behavior of glulam beams exposed to three-side fire. *Building Structure, 50*(16), 87–93. DOI: 10.19701/j.jzjg.2020.16.015. (In Chinese).
22. Zhang, J., Sun, Y., Wang, Y., Lu, C., Wang, W., & Wu, L. (2022). Experimental study on fire performance of cross laminated. *Journal of Building Structures, 43*(9), 115–127. DOI: 10.14006/j.jzjgxb.2020.0603. (In Chinese).
23. Van Hai, L., Pham, D. H., & Kim, J. (2022). Effect of Bleaching and Hot-Pressing Conditions on Mechanical Properties of Compressed Wood. *Polymers, 14*(14). DOI: 10.3390/polym14142901.
24. Wei X., & Guo W. (2023). Study on the bending behavior of steel splice joint between laminated wood elements. *Architecture Technology, 54*(20), 2505–2508. (In Chinese).
25. Yao, L., Song, F., Wei, M., Wang, A., Xu, X., Chen, Z., … Jiang, P. (2025). Flame-Retardant Wood Scrimber/Plywood Composites: Preparation, Characterization, and Enhanced Structural Performance. *Polymers, 17*(18). DOI: 10.3390/polym17182556.
26. Dominguez-Santos, D., Mora-Melia, D., Pincheira-Orellana, G., Ballesteros-Pérez, P., & Retamal-Bravo, C. (2019). Mechanical Properties and Seismic Performance of Wood-Concrete Composite Blocks for Building Construction. *Materials, 12*(9). DOI: 10.3390/ma12091500.
27. Wang, Z., Wei, Y., Jiang, J., Zhao, K., & Zheng, K. (2020). Comparative Study on Mechanical Behavior of Bamboo-Concrete Connections and Wood-Concrete Connections. *Frontiers in Materials, 7*. DOI: 10.3389/fmats.2020.587580.
28. Giv, A.N., Asante, B., Yan, L., & Kasal, B. (2024). Shear performance and durability of adhesively bonded spruce wood-concrete composite joints: Effects of indoor and outdoor environmental conditions, mechanical load, and their coupled effect. *Construction and building materials, 436*. DOI: 10.1016/j.conbuildmat.2024.136905.
29. Pan, Y., Tannert, T., Kaushik, K., Xiong, H., & Ventura, C.E. (2021). Seismic performance of a proposed wood-concrete hybrid system for high-rise buildings. *Engineering Structures, 238*. DOI: 10.1016/j.engstruct.2021.112194.
30. Gan, Z., He, M., Li, Z., & Sun, Y. (2025). Buckling performance of a two-span nail-laminated timber-concrete composite floor under axial load. *China Civil Engineering Journal, 58*(9), 55–63. DOI: 10.15951/j.tmgcxb.24010068. (In Chinese).

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ДРЕВЕСИНА КАК КОНСТРУКЦИОННЫЙ МАТЕРИАЛ: СОВРЕМЕННОЕ СОСТОЯНИЕ ВОПРОСА, ПРОБЛЕМЫ, ПЕРСПЕКТИВЫ

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В статье представлен систематический обзор последних разработок в области изгибаемых и внецентренно сжатых элементов, композитных элементов из дерева и бетона, с акцентом актуальное состояние вопроса, включая механические характеристики древесины, процессы изготовления, огнестойкость, механизмы *сопряжения и оценку долговечности. В результате анализа было установлено, что клееная древесина, благодаря своей многослойной структуре, высокой прочности при изгибе и контролируемой работе под нагрузкой, имеет явные преимущества по огнестойкости, изгибу и применению в композитных системах, хотя работа конструкции при высоких температурах и длительном воздействии нагрузки требует дополнительных исследований. Несмотря на прогресс в изучении изгибаемых деревянных конструкций, обусловленный достижениями в области гидротермального размягчения, локального уплотнения, модификации материалов и инноваций в области формирования поперечного сечения, остаются проблемы, связанные со стабильностью изготовления и непрерывностью производственного процесса для крупногабаритных конструкций. Конструкции из древесно-бетонных композитных материалов обладают высокой пластичностью, рассеиванием энергии и сейсмическими характеристиками, но остается неопределенность в отношении долгосрочной прочности соединений и работы в условиях неблагоприятной окружающей среды. В целом древесина как конструкционный материал развивается от изучения отдельных его свойств к разработке многомасштабной парадигмы «материал-поверхность-структура-окружающая среда». Дальнейшая работа в данной области должна углубить понимание механики, многомасштабного моделирования, индустриализации процессов и исследований в области устойчивого применения данных конструкций для создания высокопроизводительных деревянных конструкционных систем.*

Ключевые слова: *строительство из древесины, композитные конструкции из дерева и бетона, устойчивость, сжатие, изгиб.*