American Journal of Biodiversity
https://biojournals.us/index.php/AJB
ISSN: 2997-3600

Engineered Wood Products: Manufacturing Technologies, Mechanical Performance, and Structural Applications – A Review

Omaima A Hasan, Mohammed Jamal Hadi
Department of Forestry, College of Agriculture, University of Kirkuk, Kirkuk, Iraq

Received: 2025, 24, Nov
Accepted: 2025, 26, Dec
Published: 2026, 27, Jan

Abstract: Engineered wood products have been one of the new trends in the construction industry as they have high mechanical strength, good use of raw materials, and they promote sustainable construction. The products used are used to fill many of the shortcomings of solid sawn timber, which include instability of the material in terms of variability and dimensions, by recrystallising the tree constituents using highly regulated manufacturing processes. As a result, the review is a synthesis of engineered wood products, which focuses on the manufacturing process, the mechanical and physical characteristics of wood products, and their structural use. The research paper explores the main types of engineered wood products, which include glued-laminated timber, laminated veneer lumber, cross-laminated timber, plywood, and oriented strand board with references to the structural behaviour and adaptation in the modern construction systems. The main design issues such as performance in connection, fire resistance, seismic behaviour, and long-term endurance are addressed in the frames of the available research results. In addition, the review also determines existing problems and lays out research opportunities in the future concerning moisture sensitivity, environmental performance, and hybrid structural systems. Generally, the review indicates that the engineered wood products are a viable and viable substitute to conventional construction materials. It is believed that the value added by these materials in future in building resilient, low-carbon building systems will be further added due to the continued technological development, performance-based design approaches, and the development of sustainable resource utilisation tools in the future.

Keywords: Mass timber; Cross-laminated timber; Structural application

Introduction

There is a growing need to design sustainable, high performance and efficient building materials that the construction sector is facing. The use of engineered wood products (EWPs) has become a viable alternative alternative to the traditional construction products including concrete and steel due to their high material uniformity, mechanical stability, and structural performance. Their increased use can be seen as a result of technological progress in the field of wood engineering and an overall tendency to go green in the construction industry (Forest Products Laboratory [FPL], 2021). Wood-based products have also been seen to have the ability of storing carbon dioxide over the life of the product hence helping to reduce climate-change. Engineered wood products can significantly lower the total building carbon footprint when used as substitutes to materials with high energy requirements (Gustavsson et al., 2006).

Engineered Wood Products, definition and classification. Engineered wood products are characterized as some type of wood products produced by companies bonding wood products, i.e. veneers, strands, lamellae, or fibers, with adhesives under controlled conditions. The method of manufacturing allows optimization of the fiber orientation, minimization of natural defects, and manufacturing of materials with predictable and consistent mechanical properties (APA – The Engineered Wood Association, 2018). Such engineered wood products as plywood, oriented strand board (OSB), glued laminated timber (glulam), laminated veneer lumber (LVL) and cross-laminated timber (CLT) are common. The products are customized towards applications either structural or non-structural depending on internal structure, thickness, and load bearing capacity. The structural types to which these products are used extensively include floors, walls, roof, beam, column, and large-span structural systems (FPL, 2021).

Engineered Wood Products Development History. The development of the engineered wood products can be traced down to the first half of the twentieth century when plywood was introduced as a structural panel material. It was the invention of synthetic adhesives in the middle of the twentieth century that facilitated the evolution of wood composite technology, and made OSB, glulam, and LVL commercially viable (Falk, 2010). More recently, the advent of mass timber construction systems (especially, cross-laminated timber), has increased the structural capabilities of wood in multi-story and non-residential structures. First invented in Europe in the 1990s, CLT has gained popularity on a global level because of its strength and dimensional stability, prefabrication and modular construction (Brandner et al., 2016).

Benefits of Engineered Wood Products over Solid Timber. Engineered wood products have better uniformity and structural reliability as compared to solid sawn wood. This is because the redistribution, as well as alignment of the wood fibers during the manufacturing process, reduces the effect of knots, deviations, and other natural defects, which guarantee uniformity of strength and stiffness (APA, 2018). In addition, the engineered products in the field of wood can result in effective use of smaller-diameter logs, weaker timber materials and the facilitation of forest management and the minimization of material waste. Structurally, EWPs have a better strength-to-weight ratio, greater stability in their dimensions, and better performance in different moisture conditions, which makes them appropriate in long-span elements and advanced structural systems (Forest Products Laboratory, 2021).

The importance of the Engineered Wood Products in Sustainable Construction. The element of sustainability is now a key factor in the current practice of construction, and engineered wood products are an important factor on how to address the environmental issues. Life-cycle analysis research shows that the structural system made of wood tends to consume less embodied energy and produce less greenhouse gases emissions compared with a traditional material building system (Gustavsson et al., 2006). Moreover, construction efficiency could be increased through the implementation of prefabricated engineered wood elements, which would help to save on-site labour, reduce the construction period, and minimise wastages. With building regulations putting more weight on environmental performance, engineered wood products are likely to become an inseparable part of any sustainable construction plan in the future and in mid-rise and high-rise constructions, in particular (Brandner et al., 2016). Recent systematic reviews highlighted the need to understand modern trends and future challenges in heterogeneous developmental sectors in a holistic analytical approach, by focusing on the interplay between structural conditions and economic determinants and long-term planning (Palani, 2025a; Palani, 2025b).

Overview and Purpose of the Review. The purpose of this review is to give a thorough examination of engineered wood products in terms of their manufacturing technologies, mechanical performance and structural applications. The paper aims at synthesizing the literature and demonstrating the benefits and drawbacks of engineered wood products, outlining the existing challenges, and explaining future trends that could potentially affect their wider usage in structural engineering and the practice of construction.

Engineered Wood Products Technologies of manufacturing.

Introduction to Principles in Manufacturing. Engineered wood products are manufactured based on the reconstruction of the wood constituents in the form of composite structural materials with increased and predictably dependable functionality. With the timber, the manufacture of finely-cut elements, under a sequence of controlled conditions, of solid timber, and their reconnection under a sequence of controlled conditions with adhesives, manufacturers subdue the material variability, and optimise mechanical response.

The given methodology helps to allow efficient use of raw material stocks and maintain the quality and structural integrity (Forest Products Laboratory [FPL], 2021). Engineered wood production technologies are different according to typology of products, geometry and application. However, most of the processes involve general steps in a sequential manner such as the preparation of raw materials, the use of the adhesives, attaching of the elements, the pressing or curing of the process, and quality check. Choice of Raw Materials and Wood Species. Raw material choice is one of the most important predeterminants of the work of engineered wood products. Spruce, pine, fir, and Douglas fir are the most common softwoods that are adopted due to their favorable strength-to-weight ratios, high availability, and can be easily processed. Some geographical areas are also using hardwood species especially in veneer-based products which require high density and strength (Falk, 2010). The production of engineered wood allows the use of thin-diameter logs and lower grade timber, which otherwise may not be useful in producing sawn lumber. This increases the efficiency of resources and supports the practices of sustainable forestry management (APA – The Engineered Wood Association, 2018).

Bonding Technologies and Adhesives. Adhesives are placed in the middle of performance and durability of engineered wood products. Most of the commonly used adhesive systems include phenol-formaldehyde (PF), phenol-resorcinol-formaldehyde (PRF), melamine-ureaformaldehyde (MUF), and polyurethane (PUR). Adhesive depends on the moisture resistance, conditions of curing, exposure to environmental factors, and structural necessities (Frihart, 2015). The quality of bonding has a direct effect on the load transfer between the elements of wood and, therefore, the mechanical performance of the final product. Contemporary production methods impose strict requirements on the formulation of adhesives, rate of spread, temperature during pressing, and curing time in order to design long-lasting and reliable bonds (FPL, 2021). Major Engineered Wood Products Manufacturing Processes.

Plywood Plywood is manufactured by peeling logs, drying them, gluing them with paint treatments and joining them using the alternating grain directional alternating patterns. The cross-laminated structure enhances dimensional stability and increases strength in both the major directions. The resulting veneer lay-up is then hot-pressed to cure the adhesive thus creating rigid panels (Forest Products Laboratory, 2021). Oriented Strand Board (OSB) OSB is made of wood strands which are oriented in given directions in a mechanical way in order to maximise the strength and stiffness. The strands are combined with adhesive and wax and pressed into layers in mats and pressed under high pressure and temperature. It is the strand orientation that differentiates OSB among other wood-based panels, as well as, it is another factor that would decide its structural performance (APA, 2018). The wood is glued together and made timber-like by applying a layer of veneer. Glulam is produced by bonding dimension layers of lumber at right angles to the longitudinal axis of the member. This setup helps in creation of massive/structural components that have high load carrying capacity and able to create curved or tapered shapes. Defects are either planned away or redistributed and hence structural efficiency is enhanced when compared with solid timber (Falk, 2010). Laminated Veneer Lumber (LVL) LVL is manufactured by gluing up narrow wood veneers whose grains run parallel to each other. This will result in a very strong and stiff product along its length. LVL is usually used in beams, headers, and columns whose mechanical properties need to be equal (Forest Products Laboratory, 2021). Cross-Laminated Timber (CLT) The manufacture of the CLT panels is done through laying the board layers alternately and gluing them together to create thick and solid panels. This cross-laminated design has a high level of dimensional stability, bi-directional load bearing and outstanding performance of wall and floor systems. The construction of CLT is generally associated with high precision machining and prefabrication, which makes it very well suited to the construction in a modular manner (Brandner et al., 2016). Parameters and Quality Control of the Processes.

The manufacturing conditions of moisture content, rate of adhesive spreading, pressing temperature, and pressing time have a great impact on the characteristics of end products of engineered wood. Off-optimal situations may lead to poor bonding or dimensional instability or reduced mechanical performance (Frihart, 2015). Quality control measures are thus necessary and usually include visual control, mechanical tests, bond-line test and compliance to the applicable standards. International standards and certification systems guarantee that the engineered wood products comply with the structural and durability needs to be used in the field of their application (APA, 2018). Engineered Wood Manufacturing Technological Innovations. The recent developments in engineered wood production revolve around an improvement in sustainability, performance and productivity of production. They consist of the creation of low-emission adhesives, bio-based adhesives, the greater automation and digitalization of the manufacturing process and advanced prefabrication methods. In addition, a hybrid product, which combines the properties of wood with others: concrete or steel, are under study to advance the structural performance and design adaptability further (Brandner et al., 2016; FPL, 2021).

Engineered Wood Products: Mechanical Properties.

The mechanical behaviour of engineered wood products is a critical factor that determines their appropriateness in structural use. Due to their crafted composition and a well-managed manufacturing process, engineered wood products (EWPs) tend to have more predictable and reproducible mechanical behaviour compared to solid sawn timber. It is the careful rearrangement and orientation of wood fibres, along with the use of the high-quality adhesive bonding, the results of which are the increased strength and stiffness properties (Forest Products Laboratory [FPL], 2021). Among the most important mechanical parameters in structural design, one may single out bending strength and modulus of elasticity. There are products like glulam, LVL, and CLT that possess significant bending abilities making these products suitable in beams, slabs, and load-bearing wall structures. These materials are shaped in a layered construction that makes them easier to distribute stress and thus enhance load-bearing efficiency (APA – The Engineered Wood Association, 2018).

Strength Characteristics under Loading modes of strengths. Engineered wood products are designed to resist several loading modes such as tension compression shear and bending. The parallelism of the wood fibres in glulam and LVL creates high tensile and compressive strength across the grain direction, which increases the efficiency in linear structural member (beams and columns) (Falk, 2010). The shear performance takes special significance in products of the type of panel which includes plywood, OSB, and CLT. In such materials, the lines of adhesive bonds and the orientation of layers are a determining factor in the transfer of shear stresses across layers. Empirical research also shows that cross-laminated designs enhance both in-plane and out-of-plane shear strength, hence leading to the overall stability of structural systems (Brandner et al., 2016). Physical Properties and Moisture -Related Behaviour. The density and moisture-related behaviour of engineered wood products has a vast impact on their mechanical performance and long-term stability because the physical properties of wood products are closely connected. Density depends on the type of wood, product and manufacturing process and it shows a strong relationship with other characteristics of strength and stiffness (Forest Products Laboratory, 2021). The moisture content has an influence on the dimensional stability, mechanical properties, and service life. The engineered wood products tend to have higher dimensional stability compared to solid timber since they have a layered structure and limited swell and shrinkage. However, even extended exposure to high levels of humidity or ingress of moisture can in turn trigger loss in strength and stiffness when not properly managed by design and protective actions (Siau, 1995). Effects of Fibre Orientation and Lay up Constructions. Engineered wood products have fundamental design variables in fibre orientation and layup configuration. Fibre orientation in veneer- and strand-based products, including LVL and OSB, is maximised to achieve maximum primary load direction strength. Cross-laminated products, on the other hand, lay fibres at right angles giving the products multidirectional strength and stiffness (APA, 2018). In CLT, dimensional stability and load distribution is significantly increased by the alternating orientation of layers. Such a design also enhances the panel redundancy such that the panels are able to sustain loads even when local defects or damages occur (Brandner et al., 2016). Long-term Performance: Creep and Durability. The long-term performance is one of the issues that are critical when structural utilisation of engineered wood product is considered. Wood-based materials can have creep behaviour performance under constant load, and this can eventually lead to creep deformation. The creep behaviour of engineered wood products is generally predictable and can be accommodated in the structural design by appropriately modifying the factors of modification required in design codes (Forest Products Laboratory, 2021). The durability would depend on the exposure to the environment, moisture, and biological agents. Although engineered wood products lack any intrinsic resistance to decayed, careful detailing, moisture management, and protective measures can significantly increase their service life. EWPs can perform similarly to the conventional construction materials when used in lieu of their standard design requirements (Siau, 1995; Falk, 2010).

The summary of mechanical and physical performance will be provided. On the whole, engineered wood products combine positive mechanical characteristics with predictable physical performance making them highly adaptable to a broad range of structural uses. Their engineered character allows the designers predict performance with a high degree of reliability, optimise the utilisation of materials and meet the ever-increasing structural and environmental requirements.

These properties form the basis of the growing use of engineered wood products in modern building systems.

Design and Applications of Engineered Wood Products Structurally and Structurally.

Engineered Wood Product Structural Use in Buildings. Designed wood products have reached a growing status in structural engineering, which can be explained by its versatility and positive mechanical properties. They are widely used in both residential, commercial, and industrial buildings as primary load-supporting elements, i.e. beams, columns, floors, walls, and roof systems. The ability to produce mass structural elements of uniform quality has widened the use of timber to the application in low rise buildings (Green and Karsh, 2012). Over the past few years, the spread of the mass timber system has enabled the construction of the multi-storey buildings using engineered wood assembly. Cross-laminated timber (CLT), glued-laminated timber (glulam), and laminated veneer lumber (LVL) structural configurations have proven to be sufficiently strong and stiff to meet modern building demands and provide such advantages as lesser self-weight and faster on-site construction (Ceccotti, 2008). Structural Behaviour andLoadTransferMechanisms. The junctions and the interactions between the individual constituents determine the structural performance of engineered wood assemblies. Engineered wood product (EWP) structures undergo load transfer using the axially, bending, and shear stresses spread across members and panels.

Bidirectional distribution of loads and structural redundancy in general are the plate-like properties that the laminated construction of the component parts, including CLT, possesses (Gagnon and Pirvu, 2011). The foreseeable mechanical behaviour of engineered wood products enables engineers to use known methods of analysis with impunity. However, when designing anisotrophic and time-varying responses are to be carefully taken into account, especially in long-span elements and heavy loaded systems (Kremer and Symmons, 2015).

Connections and Joint Systems. In the engineered wood, connections are vital factors of performance and safety. Mechanical fasteners such as dowels, screws, nails and steel plates are traditionally used in the joining of the EWP elements. These connections are mainly determined by the stiffness, strength, and ductility which determines the global response of the structure particularly during the lateral loading scenario (Blass and Fellmoser, 2004). The modern design paradigms are emphasizing more on the use of ductile joint system to improve structural resilience. In seismic, effective energy dissipation is primarily accomplished by the design of connections that are controlled to degenerate instead of brittle failure of wooden members and hence connection design becomes a key component of engineered timber construction (Ceccotti et al., 2013). Fire-Safety Design Fire Performance. The timber engineering products are important structural components to which fire performance is a key consideration. Large-cross-section timber elements can demonstrate reasonable levels of fire resistance contrary to common belief because of the creation of a protective layer of char that provides protection to the interior and slows down the deterioration. The anticipated charring behaviour allows the creation of timber structure that meets fire-resistance standards through the calculated loss of sections (Buchanan and Abu, 2017). CLT and glulam are engineered wood products which when correctly designed and detailed have been found to perform reasonably well when subjected to fire. The fire-resistance ratings can be achieved by using sacrificial layers along with protective cladding and adherence to fire-design standards (Schmid et al., 2014).

Wind and Seismic Performance of Structures made of Engineered wood. The ability of timber engineered buildings to perform well under seismic and wind loading has been commendable; this has been due to relatively low mass and inherent flexibility. The self-weight decrease reduces seismic forces and used ductile joint systems allow the buildings to dissipate the energy in case of dynamic events (Ceccotti et al., 2013). Analytical and experimental studies have suggested that timber structures with multiple storeys are capable of giving reasonable seismic performance as long as they are designed in accordance with the capacity-based principles.

Similar advantages have been noted in wind loading where engineered wood systems have demonstrated to be sufficiently stiff and vibration controlled when they are detailed accordingly (Kremer and Symmons, 2015).

Codes, Standards and Design Frameworks. The use of engineered wood products has been made very easy through the introduction of national and international design codes. Thelandersson and Larsen (2003) indicate that design guidelines of timber and engineered timber structures, including strength verification and serviceability limits, and fire design, are prescribed by Eurocode 5, the National Design Specification (NDS) of Wood Construction. Continued improvement of these codes also shows the development of research, testing and experience, especially with mass timber systems. It is expected that further harmonisation of codes and performance based design methods will enhance further streamlining of engineered wood products to mainstream structural engineering practice.

The Future Trends, Research Directions and Challenges of Engineered Wood Products.

Technical and Material Problems. Although the use of engineered wood products in structural application has been growing, a number of technical issues still prevail. First of all, the vulnerability of wood-related materials to moisture and environmental impact is still a burning issue. Poor moisture management may lead to dimensional, biological degradation and reduced mechanical performance especially in exterior or high-humidity condition (Dinwoodie, 2000). The other difficulty is related to long-term performance of bond lines. Modern adhesives are very robust but their behaviour during prolonged mechanical loading, changes in temperature and exposure to the environment remains a subject of very intensive study. Regularity in the quality of bonding of large structural parts is a requisite towards structural safety and serviceability (Frihart and Hunt, 2010).

Longevity, Service life and Environmental exposure. One of the major conditions of service life of engineered wood products is durability. When there is not enough protection, the structural integrity may be destroyed due to exposure to moisture, fungi, and insects. Moisture barriers, intricate drainage facilities and protective coating are examples of design measures that greatly increase the durability, however, additional studies are necessary to expand such solutions to the needs of various climatic settings (Meyer & Brischke, 2015). Moreover, further evaluation of engineered wood products is required in harsh conditions, including coastal or industrial settings. An in-depth knowledge of how the environment interacts with the degradation mechanism in timber-based structures is essential in ensuring that timber based structures have a long life span (Dinwoodie, 2000).

Environmental Impact and Life Cycle. The key benefit of engineered wood products lies often in the environmental performance of the products as a key advantage in comparison to the traditional building materials. Nevertheless, any rigorous life-cycle analysis should not be limited to looking at only the storage of carbon, but also to the carbon emission rates linked to manufacturing, transportation, and end-of-life conditions. Factors like production of adhesives and energy used in the processing affect the overall environmental impact of engineered wood systems (Werner and atable Richter, 2007). Recent studies are paying more attention to the enhancement of the environmental profile of engineered wood products by means of using bio-based adhesives, more possibilities of recycle, and circular-economy approaches. The purpose of these developments is to enable the timber based construction to further enhance its sustainability credentials (Hill, 2011).

Hybrid Systems and Developed Structural Ideas. Hybrid structural systems involving the use of engineered wood products with other materials like concrete or steel is an appropriate trend in the modern construction. Such systems aim at exploiting the strengths of every material and reducing the drawbacks of each material. These are timber-concrete composite floors, hybrid high-rise structures, which are better in stiffness, vibration, and fire resistance (Yeoh et al., 2011). The innovative approaches to structural concepts have been made possible by the progress that has been made in digital design tools and numerical modelling. The optimised utilisation of engineered wood products is made possible by the parametric design, the building information modelling (BIM), and the performance-based engineering methods, allowing the incorporation of the complex structural systems (Gerber & Lin, 2013). New Technologies and Future Research. The emerging studies in the area of the engineered wood products have focused on the higher level of performance of the material, widening of the field of application, and the efficiency of the manufacturing.

Nanotechnology advances also include nano-enhanced adhesives and coating that have the potential to increase the durability and resistance to moisture. Developed methods of testing and monitoring are also used in explaining long-term behaviour and structural timber systems health (Frangi et al., 2014). There is also a potential in another direction, the creation of performance-based design frameworks based on the mass timber buildings.

The approaches also seek to go beyond the requirements of prescriptive code, providing more flexibility in design and maintain safety and reliability (Van de Kuilen et al., 2011). Concluding Remarks Engineered wood products represent the emerging category of construction materials that have an enormous potential to promote sustainable and efficient building activity. Despite the significant advancements made in the manufacturing technologies and mechanical performance, as well as in structure application, it is necessary to continue the research to meet the current issues of durability, environmental exposure, and long-term performance.

It can be predicted that new materials science, digital design, and hybrid construction systems will further increase the importance of engineered wood products in the built environment. The engineered wood products can be a key factor in the shift towards a more sustainable and resilient construction system through further innovation and interdisciplinary research.

Conclusion

Engineered wood products are a particularly important shift in modern construction, which involves the combination of the natural advantages of timber with extremely accurate methods of manufacturing products that make it better structurally and in the use of its material. These products provide superior mechanical performance, dimensional stability and design flexibility as compared to conventional sawn timber through highly controlled production process.

As shown in this review, engineered timber products, such as glued -laminated timber (glulam), laminated veneer lumber (LVL), cross-laminated timber (CLT), plywood, and oriented strand board (OSB), are extremely suitable when considering a wide range of structural applications, both low-rise and multi-storey and hybrid construction. Their positive strength to weight ratio, predictable behaviour, and compatibility properties with prefabrication make them competitive substitutes to the conventional construction materials.

However, the continuing issues with regard to moisture sensitivity, long-term viability, fire behaviour and connection behaviour are again of paramount concern during the design process and use. To continue improving reliability and allow wider adoption of engineered wood products, current research and technological development, especially sustainable adhesives, hybrid structural systems, and performance-based design methods are needed.

Overall, EWPs will play an even greater role in the future of the sustainable and resilient construction industry helping to shift to low-carbon building systems and structurally-efficient resource consumption.

Future Recommendations

The next generation of a study on engineered wood products ought to focus on improving durability and moisture and biological resistance to degradation by using advanced treatment of materials and design methods. Specific consideration is needed to gain a better insight into the performance of the adhesive bond lines on the long term relative to the different environmental and loading conditions.

The recommendation is further development of sustainable and bio-based adhesives to reduce the effects of manufacturing on the environment and not compromise the structural integrity. Also, further life cycle assessment research has to be conducted in order to measure the overall environmental performance of engineered wood products, including end-of-life conditions and possibilities of recycling.

The development of hybrid structural systems which would consist of engineered wood products with concrete or steel should be promoted in order to improve structural efficiency, fire resistance, and vibration performance. Lastly, incorporation of performance based design strategies and further development of international design standards will be needed to help facilitate safe and extensive usage of engineered wood products in modern building.

References

1. APA – The Engineered Wood Association. (2018). Engineered wood construction guide. APA – The Engineered Wood Association.
2. Blass, H. J., & Fellmoser, P. (2004). Design of solid wood panels with cross layers. Proceedings of the 8th World Conference on Timber Engineering (WCTE), Lahti, Finland.
3. Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): Overview and development. European Journal of Wood and Wood Products, 74(3), 331–351. https://doi.org/10.1007/s00107-015-0999-5
4. Buchanan, A. H., & Abu, A. K. (2017). Structural design for fire safety (2nd ed.). Wiley.
5. Ceccotti, A. (2008). New technologies for construction of medium-rise buildings in seismic regions: The XLAM case. Structural Engineering International, 18(2), 156–165. https://doi.org/10.2749/101686608784218860
6. Ceccotti, A., Sandhaas, C., Okabe, M., Yasumura, M., Minowa, C., & Kawai, N. (2013). SOFIE project—3D shaking table test on a seven-story full-scale cross-laminated timber building. Earthquake Engineering & Structural Dynamics, 42(13), 2003–2021. https://doi.org/10.1002/eqe.2309
7. Dinwoodie, J. M. (2000). Timber: Its nature and behaviour (2nd ed.). E & FN Spon.
8. Falk, R. H. (2010). Wood as a sustainable building material. Forest Products Laboratory, U.S. Department of Agriculture.
9. Forest Products Laboratory. (2021). Wood handbook—Wood as an engineering material (FPL–GTR–282). U.S. Department of Agriculture, Forest Service.
10. Frangi, A., Fontana, M., Knobloch, M., & Bohnenblust, A. (2014). Fire design of timber slabs made of hollow core elements. Engineering Structures, 68, 64–73. https://doi.org/10.1016/j.engstruct.2014.02.020
11. Frihart, C. R. (2015). Wood adhesion and adhesives. In R. M. Rowell (Ed.), Handbook of wood chemistry and wood composites (2nd ed., pp. 255–307). CRC Press.
12. Frihart, C. R., & Hunt, C. G. (2010). Adhesives with wood materials—Bond formation and performance. In R. M. Rowell (Ed.), Wood handbook: Wood as an engineering material (pp. 10.1–10.24). USDA Forest Service.
13. Gagnon, S., & Pirvu, C. (2011). CLT handbook: Cross-laminated timber. FPInnovations.
14. Gerber, D. J., & Lin, S. H. E. (2013). Designing in complexity: Simulation, integration, and multidisciplinary design optimization for architecture. Simulation, 90(8), 936–959. https://doi.org/10.1177/0037549713497954

15. Green, M., & Karsh, J. (2012). The case for tall wood buildings. Wood Enterprise Coalition.
16. Gustavsson, L., Pingoud, K., & Sathre, R. (2006). Carbon dioxide balance of wood substitution: Comparing concrete- and wood-framed buildings. Mitigation and Adaptation Strategies for Global Change, 11(3), 667–691. https://doi.org/10.1007/s11027-006-7207-1
17. Hill, C. A. S. (2011). Wood modification: Chemical, thermal and other processes. John Wiley & Sons.
18. Kremer, P. D., & Symmons, M. A. (2015). Mass timber construction as an alternative to concrete and steel in the Australia building industry: A PESTEL evaluation. International Journal of Sustainable Building Technology and Urban Development, 6(3), 138–147. https://doi.org/10.1080/2093761X.2015.1030114
19. Meyer, L., & Brischke, C. (2015). Durability of wood and wood-based products. Springer.
20. Palani, P. M. R. (2025). Residential Crisis in Iraq: The Current Trends and Future Prospectus: A Review. Spanish Journal of Innovation and Integrity, 38, 121–128. Retrieved from https://sjii.es/index.php/journal/article/view/185
21. Palani, P. M. R. (2025). The Relationship of International Loans to Credit Wall (Worthiness): A Review. Spanish Journal of Innovation and Integrity, 38, 1–7. Retrieved from https://sjii.es/index.php/journal/article/view/168
22. Schmid, J., König, J., Kohler, J., & Lagerqvist, O. (2014). Fire design of cross-laminated timber structures. Engineering Structures, 84, 246–256. https://doi.org/10.1016/j.engstruct.2014.11.035
23. Siau, J. F. (1995). Wood: Influence of moisture on physical properties. Virginia Polytechnic Institute.
24. Thelandersson, S., & Larsen, H. J. (2003). Timber engineering. John Wiley & Sons.
25. Van de Kuilen, J. W. G., Ceccotti, A., Xia, Z., & He, M. (2011). Very tall wooden buildings with cross laminated timber. Procedia Engineering, 14, 1621–1628. https://doi.org/10.1016/j.proeng.2011.07.204
26. Werner, F., & Richter, K. (2007). Wooden building products in comparative LCA. The International Journal of Life Cycle Assessment, 12(7), 470–479. https://doi.org/10.1065/lca2007.04.317
27. Yeoh, D., Fragiacomo, M., De Franceschi, M., & Boonstra, M. (2011). Structural behaviour of timber–concrete composite floors. Journal of Structural Engineering, 137(8), 803–813. https://doi.org/10.1061/(ASCE)ST.1943-541X.0000406