Configuring Wood in Hybrid Timber Structures for Low-Carbon and Circular Construction

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Background

Wood is increasingly expected to deliver structural performance and verifiable lifecycle benefits, accelerating hybrid timber systems that combine timber or engineered wood products with concrete, steel, or reinforcement materials. These combinations can overcome stiffness, vibration, fire, acoustic, robustness, and constructability constraints in timber-only solutions, particularly in multi-storey and tall buildings (Pasternack et al. 2022; Abdulmalik et al. 2025). Yet classification by material pair, such as timber-concrete or timber-steel, identifies the materials but not how the structure works. The same pair may provide local reinforcement, form a composite floor, or contribute to a building-scale stability system, with implications for load transfer, stiffness distribution, interface behaviour, material demand, and end-of-life separability (Tannert et al. 2020; Kim and Kim 2022). This matters because neither high timber content nor carbon storage alone guarantees low whole-building impacts or circular recovery (Kumar et al. 2024). This study therefore reframes hybridisation according to wood's position in the load-bearing hierarchy. It develops a transferable three-level framework, locally enhanced timber elements, composite assemblies, and building-level structural systems, and explains how each level affects structural response, carbon-oriented material efficiency, connection reversibility, and design for disassembly.

Keywords: hybrid timber systems, structural configuration, load-bearing hierarchy, low-carbon construction, design for disassembly.

Materials and Methods

The study uses a conceptual and structured synthesis rather than original experiments, quantitative meta-analysis, or a full systematic review. The evidence base comprises scientific and technical sources covering hybrid timber systems, structural and serviceability performance, lifecycle carbon, connection design, reuse, and circular construction. Sources were retained when they examined wood with a complementary material at the element, assembly, or building scale and informed at least one of five analytical dimensions: structural response; subsystem coupling; embodied-carbon performance; regulatory and safety performance; or constructability and lifecycle adaptability. The synthesis proceeded in three stages: classification by integration scale, comparison across the five dimensions, and interpretation of recurring configuration logics. The results express cross-source analytical tendencies, not quantitative design rules or statistically generalisable effects.

Results and Discussion

The synthesis identifies three distinct structural roles for wood (Figure 1). Moving from element to building scale changes not only the size of the unit being analysed, but also the mechanism through which hybridisation creates performance.

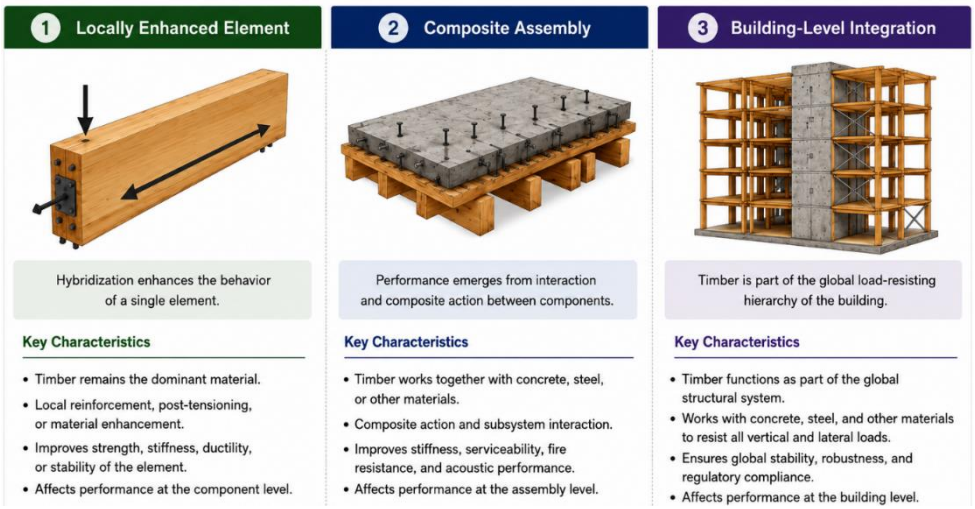

Figure 1. Configuration-based interpretation of hybrid timber systems through three structural roles of wood.

Element level. Timber remains the dominant load-bearing material, while steel tendons, plates, rods, fibre-reinforced polymers, or bio-based composites address a member-specific limitation in strength, stiffness, ductility, or durability. The global load path remains unchanged. Smaller sections or longer service life may reduce impacts, but bonded or embedded reinforcement can obstruct separation.

Assembly level. Performance emerges from interaction between components. Timber-concrete composite floors use interface shear transfer to combine timber's tensile contribution with concrete's compression capacity, mass, fire resistance, and acoustic benefits (Shephard et al. 2021). Timber-steel assemblies use steel for tensile capacity, ductility, or long spans while retaining timber's low self-weight (Loss et al. 2018; Owolabi et al. 2023). Connector stiffness, slip, time-dependent movement, and reversibility govern efficiency, repair, and reuse (Dissanayake et al. 2025).

Building level. Hybridisation becomes functional material allocation within the global load-resisting hierarchy. Timber can dominate gravity-load systems, while concrete cores or steel bracing provide lateral stiffness, robustness, fire compartmentation, or transfer capacity (Pan et al. 2021). Brock Commons illustrates how concrete cores can enable a timber-dominant superstructure (Staub-French et al. 2022). The criterion is functional value with minimum whole-building material demand, not timber quantity alone.

Cross-scale finding. The comparison does not support a universal ranking in which a higher level is automatically better. Element-level solutions directly address local constraints; assembly-level systems create interface-dependent gains and trade-offs; and building-level integration has the widest leverage over global stability and material intensity.

Across all three levels, two cross-cutting logics emerge. Carbon-oriented configuration prioritises functional equivalence, material efficiency, and avoided overdesign rather than maximum timber content. Lifecycle-oriented hybridisation treats adaptability, disassembly, reuse, and recovery as outcomes of connection design, subsystem separation, and material zoning; reusable demountable systems demonstrate the importance of interfaces (Li et al. 2024).

Conclusions

Hybrid timber construction cannot be evaluated through material selection alone. The structural, carbon, and end-of-life value of wood depends on its role in load paths, subsystem interaction, and interface reversibility. The framework therefore supports performance-oriented material allocation rather than timber-content maximisation. Its tendencies should next be tested through functionally equivalent structural comparisons, lifecycle assessment, and long-term interface evaluation.

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