Enhancing Rapid-Build Structural Assemblies with Hybrid Hardwood-Softwood Mass Timber: A Cross-Cultural Comparison

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Abstract

Hardwood timber resources are increasingly incorporated into mass timber building products in Central Europe leading to architecturally and structurally significant building outcomes; however, besides parallel strand lumber, the use of hardwood in American mass timber products is rare. In addition to solid hardwood mass timber products, hardwoods and softwoods can be combined into hybrid mass timber products that maximize the potential of each wood type. This paper presents a cross-cultural comparison of hybrid hardwood-softwood mass timber products produced in Central Europe and the United States with an emphasis on the utilization of such products in buildings designed for rapid assembly. This study focuses specifically on the performance enhancements that hardwoods have provided in softwood mass timber products developed in Central Europe and presents key cultural and economic factors that have limited the development of such high-performance hybrid mass timber products in the United States. The paper supports the position that novel architectural form and expression in mass timber can be achieved through hardwood-related structural and affective performance enhancements. The study also indicates that the slower maturation of the European mass timber market has positively influenced hardwood utilization in mass timber products. This study was conducted within the 'Wood Urbanism' research program at Virginia Tech's campus in Switzerland in 2024.

Background

Engineered Wood Product Development

Historically, wood is one of the world's most widely preferred structural building materials (Ahmed and Arocho 2020). Such widespread use in North America and Europe has impacted both rural and urban landscapes, contributed to cultural, social, and industrial development, and supported the development of novel structural and architectural approaches to building construction. Not all wood species are equally useful in building construction, and the selection of a particular wood species or product by an architect depends on a variety of factors, including availability, cost, mechanical performance, aesthetics, and other considerations (Laguarda Mallo and Espinoza 2015). Due to the diverse properties within a single species of wood, or even within a single tree or piece of lumber for that matter, different approaches to controlling the natural variability of wood have been developed. New engineered wood products (EWPs) are being continuously developed that seek to homogenize wood performance within a single product while also increasing structural performance (Sotayo et al. 2020). EWPs consist of a variety of wood fiber components depending upon the performance and aesthetic characteristics required of the EWP, as well as available machining capabilities, among other factors. EWPs consist of wood chips or fibers, veneers, or strands connected by a high-performance adhesive, and EWPs demonstrate increased strength capabilities compared to solid wood products of equal volume. (Heräjärvi et al. 2004). EWPs are an important structural building product specified by architects and a variety of EWP performance factors influence the architectural specification process (Emre Ilgın and Karjalainen 2022). "Initially, much development of EWP was focused on creating substitute products capable of replacing small dimension sawn lumber and boards as primary elements in light-frame building superstructures (Gong 2019, 1)," however mass timber product development has been expanding in recent decades to provide structural products for larger building applications with more rapid assembly times. Mass timber is inherently a rapid-build construction system as the elements are prefabricated to a high degree of precision for quick onsite assembly.

Hybrid Mass Timber Development

Mass timber products are a type of EWP that typically include large, structural, composite wood elements that are designed to maximize wood fiber performance for spatial applications (Kremer and Symmons 2015; Harte 2017). Common mass timber products include cross-laminated timber (CLT), glue-laminated timber (glulam), laminated veneer lumber (LVL), nail-laminated timber (NLT), and dowel-laminated timber (DLT) (Gong 2019). Mass timber products are widely used in the United States and Europe in particular for educational, residential, and commercial uses (Ahmed and Arocho 2020; The Beck Group 2018; Quesada et al. 2020). Due to building code requirements and industrial capacity in the United States and Europe, softwood lumber is by far the most utilized wood type for mass timber products.

However, researchers are increasingly focused on how hardwood lumber can be used in mass timber products, either on its own as a solid hardwood mass timber product, or in combination with softwood lumber to create hybrid mass timber products (Adhikari et al. 2020; Espinoza and Buehlmann 2018; Adhikari, Bond, and Quesada 2023; Aicher, Hirsch, and Christian 2016; Franke 2016; Essoua and Blanchet 2017; Ogunruku et al. 2024). In hybrid mass timber products, denser, stronger hardwood lumber is typically used in combination with softwood lumber to increase mass timber performance (Wang, Gong, and Chui 2015). As mass timber manufacturers have facilities optimized for softwood mass timber production and not hardwood mass timber production – due to the highly disproportionate demand for softwood mass timber over hardwood mass timber – the incorporation of hardwood lumber into the mass timber production process leads to various inefficiencies that increase production time and cost. Such wood grading and production inefficiencies have limited the interest of manufacturers to include hardwood lumber in the production process (Adhikari et al. 2020).

Certain cultural and economic factors have led to a relatively widespread use of hybrid mass timber (HMT) products in Europe that in turn has demonstrated that novel architectural form and aesthetic can be achieved with such products (Kuzman and Sandberg 2023). In the United States, however, hybrid mass timber has rarely been used outside of the research lab environment, and few, if any, peer-reviewed publications exist for architects regarding specific information on European HMT precedents or the factors that have limited HMT use in the United States.

Objectives

This study provides a cross-cultural comparison of the current state of hybrid mass timber utilization in the United States and Europe for architects. Within Europe, this review focuses on HMT produced or used in Central Europe including Austria, Germany, and Switzerland due to the region's relatively widespread and advanced uses of HMT in full-scale, completed buildings. The structural and aesthetic performance enhancements provided by hardwood lumber inclusion in softwood mass timber products are considered in case study buildings that were each selected due to their employment of rapid-build structural assemblies. By focusing on buildings with rapid-build structural assemblies, as generally found in the industrial and commercial building sectors, a greater degree of clarity can be provided about how hardwoods specifically enhance the structural and aesthetic performance of the building, as compared to residential or cultural buildings where the building design process is influenced to a greater degree by a more diverse set of concerns beyond structural and cost efficiency. As HMT products are not used in the United States in contrast to Europe, the author will focus on Europe, but present key cultural and economic factors that have limited the development and utilization of such high-performance hybrid mass timber products in the United States.

Methods

This study includes first-person data acquisition by the author following research visits to the specific case study buildings, architectural offices, and production facilities seminal to the case study buildings' realization. These include, but are not limited to, technical architectural visits to the Sports Centre Sargans, Suurstoffi 22 and Tamedia office buildings, and the International House Sydney, as well as the architectural offices of Hildebrand (Zurich) and Shigaru Ban Architects (New York), and a visit to Blumer Lehmann's Gossau headquarters in Switzerland. First-person visits by the author were conducted between 2019 and 2025. Additionally, oral history interviews with three American mass timber consultants were conducted virtually in 2024. The interviews documented their past personal experiences and help to contextualize the buildings, or material uses as part of the historic evolution/continuum of the industry.

Hybrid Mass Timber Production and Use in Central Europe

Hardwood timber has been used in Central Europe for centuries, from cities built on oak piles to 19th-century beech wood block paving and railway sleepers. Oak was a common and high-performance structural material used frequently for half-timber houses. However, despite the prevalence of hardwood species in Central European forests, some hardwoods such as Beech – one of the most common species in Central Europe – exhibit a very poor moisture tolerance and thus were not used as frequently as might be expected ("Application of Hardwood for Glued Laminated Timber in Europe" 2020, 609) (Detail Magazine 2021). The use of hardwoods in structural building products in Europe has a long history, yet during the modern period structural uses for hardwood lumber were largely forgotten. Today, hardwoods are used in Central Europe to a very small but growing extent for structural building applications. Hardwood upcycling and utilization within high-performance mass timber products was first demonstrated in 2009 and 2010 in public and private buildings, respectively (Merz, Niemann, and Torno 2021d). Such recent uses illustrate the emerging potential of hardwood lumber in European mass timber products.

Forest Evolution in Central Europe

The growing use of hardwood lumber in mass timber building products in Central Europe is logical as the changing forest composition, from more softwood to more hardwood, parallels the diversification of solely softwood mass timber products into hybrid and solid hardwood mass timber products. Central European forest composition is shifting to a more hardwood dominant condition due to climate change and evolving forestry practices, from more Spruce and Pine oriented to more Beech oriented in Germany, for example (Sciomenta et al. 2021). When comparing timber volume in "German Forests (1.4 billion m3 hardwood) and the annual growth (12.36 m3 hardwood) with the actual consumption … it is clear on the basis of the quantities of undressed timber that there is nothing to stop a manifold increase in the use of hardwood in construction (Lattke, Niemann, and Richter 2021, 17)." Thus forest health is not degraded but rather improved by the sustainable harvesting of more German Beech, for example (Pasternack et al. 2022; Merz, Niemann, and Torno 2021b). As such, the case for hardwood use in hybrid mass timber products is significantly bolstered by changing forest composition and the proven ability in Europe to harvest wood sustainably (Hofmeister and Schoof 2023, 40).

HMT Access and Utilization

In terms of regulations governing the use of hardwood or hybrid mass timber products in Europe, “Building with Hardwood” by Merz, Niemann, Torno provides a comprehensive overview of regulatory and code approval for hardwood and hybrid mass timber products, including hybrid glulam (Merz, Niemann, and Torno 2021c). In general, it is important to note that compared to the United States, performance-based building regulations in Europe have helped support the development of unique structural wood products. Both softwood mass timber elements and hardwood mass timber elements are more commonly available than hybrid hardwood-softwood mass timber elements (HMT). HMT elements are usually produced by special order and with specific dimensions for one-off structural applications that require unique solutions (Merz, Niemann, and Torno 2021c). While hybrid mass timber products are still rarely specified by building professionals, and relatedly only a few European producers have produced hybrid mass timber products for special commercial application in Europe, Hess Timber Gmbh – 75% majority owned by Hasslacher Holding GmBH – has been a leader in Europe with innovative HMT products utilized around the world, including in Australia, the United Kingdom, and the Middle East. Specifically, Hess Timber supplies a GLU Hybrid custom product that has included Beech, Ash, American White Oak, Oak, and Chestnut as a hardwood pairing with softwoods, namely Spruce (Hess Timber 2025). Other more standard industrially produced HMT products in Europe include hybrid glulams featuring hardwood top and bottom layers with softwood in-between, parallel softwood glulams sandwiched around a central layer of hardwood LVL, and products that pair location-specific applications of ash with a majority softwood glulam beam. European researchers have been testing many other alternative hardwood-softwood HMT assemblies (Aicher, Hirsch, and Christian 2016; Aicher and Tapia 2018; Wang, Gong, and Chui 2015; Sciomenta et al. 2021) – see also the International Conference on Hardwood Processing and the hardwood sections of the World Conference on Timber Engineering for further research. In the following sections, two buildings will be presented including their specific applications of HMT. Each case will be presented from both a structural and aesthetic position.

Case Studies: Hybrid Mass Timber in Practice

Case Study 1 – Hybrid Glulam, Sports Centre Sargans
Architect: Hildebrand Studios; Ruprecht Architekten
Location: Sargans, CH; Year: 2012

Three primary factors influenced the design of the Sports Centre in Sargans, Switzerland, namely the desire (1) to replace an existing sports hall in a sustainable manner (2) to reuse existing pile foundations on a marshy site, and (3) to construct the building quickly (Schittich 2015). The project’s need to span large distances of over 10m and be constructed quickly supported the selection of a

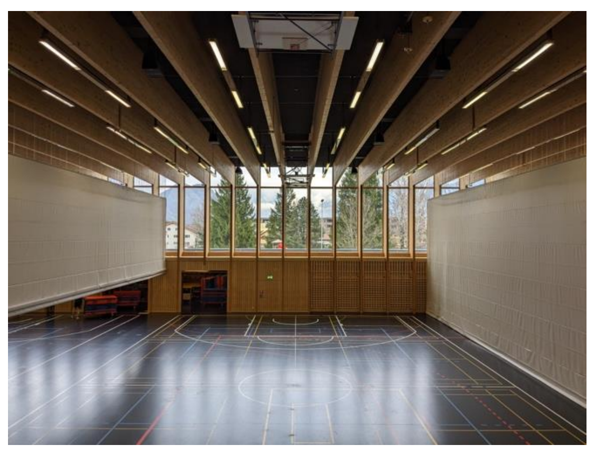


Fig. 1. Sports Centre Sargans. Photo Credit: Author

mass timber structural system – a vertical and horizontal glulam assembly with composite reinforcing wood board infill panels. Slender, tall glue-laminated structural "U" frames (Fig. 1) were developed that utilized different strength classes of softwoods and include grouted steel anchor rods at the corners that prestress and stiffen the frame – see GSA system developed by neue Holzbau AG in Lungern, CH (Jacob-Freitag 2016). In terms of the assembly, structural floor anchors were installed first and then the entire "U" shaped mass timber frame was lifted by crane and set into place atop the anchors. The architects noted the uniqueness and the conceptual simplicity of the assembly method, as well as the rapid speed of construction that was realized on the project (Hildebrand 2024).

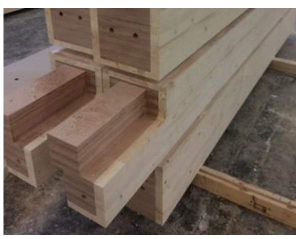
Fig. 2. Ash and Spruce Joint. Photo Credit: S. Jacob-Freitag (See European Standard EN 14080 for GL strength classes)

During the design phase it became apparent that the structural needs of some horizontal spruce glulam beams would exceed their structural capacity, for example in the bathroom areas and auxiliary areas under a wood-concrete composite ceiling. By including ash in the bathroom ceiling softwood beams (Fig. 2), a GL 40 strength class was achieved as compared to a GL 36 strength class for the solely softwood (spruce) frame posts and GL 28h frame beams used elsewhere (Lattke, Niemann, and Richter 2021, 20; Jacob-Freitag 2016). The use of ash allowed the beam cross sections to be about 60% smaller due the approximately 50% structural performance increase in terms of bending and shear strength that the ash wood provided (Jacob-Freitag 2013). Ash can be effectively used in combination with spruce, an advantage for the project as ash is approximately three times more expensive than spruce.

There was a desire by the design team to keep the same beam cross-sectional width and spacing throughout the building to support the affective, rhythmic aesthetic of the spatial experience. The stronger ash-spruce glulam beams allowed the design team to achieve this aesthetic and performative goal. It is worth noting that the HMT beams are not a typical hardwood-softwood glulam arrangement whereby the hardwood layers are only on the top and bottom of the beam. Rather, ash is placed specifically where the highest load concentrations occur. This specialized application of hardwood lumber in a softwood beam required the manufacturer, neue Holzbau AG, to carefully coordinate with the project engineer and architect well in advance to achieve a proper, rapid-build structural assembly. Prior to the 2012 building completion date, spruce/ash glulam had only been used in bridge construction, and even that application was very rare (Jacob-Freitag 2016).

Case Study 2 – Hybrid Glulam, Suurstoffi 22
Architect: Burkard Meyer Architekten; Year: 2020

Built in the new 'climate neutral' quarter in Risch-Rotkreuz, Switzerland, Burkard Meyer Architekten employed multiple unique design solutions to achieve a progressive environmental, structural, and aesthetic end product in Suurstoffi 22, the first timber high rise in Switzerland. Built on a concrete plinth and around concrete egress and structural cores, a softwood-hardwood mass timber structural frame is set on an 11.5m interval for the interior office areas and a 5.75m interval for the more exterior façade zones (Merz, Niemann, and Torno 2021a, 76). During the design process, the structural engineers MWV Bauingenieure determined that a unique solution should be pursued for the interior columns and girders closest to the central concrete circulation core. Due the heavy loading condition of those elements, if they were to be fabricated in spruce then the size of the elements would be problematically large. The design team instead employed a Pollmeier-made, BauBuche Beech laminated veneer lumber (LVL) product (Fig. 3, 4) that as a hardwood product could carry significantly higher loads than spruce but still maintain a small cross section. In fact, the Beech LVL was so structurally efficient that its cross section was small enough to allow the design team to sheath the Beech LVL in softwood lumber in order to maintain a light-wood aesthetic while still matching the cross-sectional dimensions of the solid spruce façade (outer) glulam



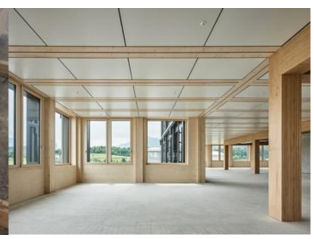


Fig. 3, (left) Pollmeier BauBuche Beech LVL column with spruce. Photo Credit: HESS Timber

Fig. 4, (right) Completed Building. Photo Credit: Burkard Meyer Architekten

columns. By pairing high-performance Beech LVL with a softwood, the design team was able to accommodate for the disproportionately high interior column loading situation while achieving their aesthetic goals. Beech LVL is noticeably darker than spruce due to both the aesthetic differences between the wood species, as well as the higher glue content of LVL as compared to a softwood glulam. Additionally, the BauBuche GL70 has a 147% higher compressive strength and a 192% higher bending strength than standard GL24 glulams (Lennartz, Marc 2025). According to Andreas Hirschbul of the timber construction contractor ERNE AG, the available space of the building was able to be optimized while keeping within the maximum building height limitations using Beech LVL. The increased structural performance of the hardwood LVL girders allowed the design team to add two additional stories to the building and stay under the height limit, as opposed to softwood girders that would have been approximately twice as thick. Additionally, “softwood glulam of GL28 or better – especially in the quantity required here – is virtually impossible to get on the market (Torno, Stefan 2021, 80).” The project is also unique in that the concrete core approach was optimized for the precision of timber construction as the floors and core were built at the same time to speed construction. This is a quite unique approach as two different trades were working side by side – the characteristic imprecision of concrete as compared to mass timber was accommodated for in the rapid-build assembly (Lennartz, Marc 2025). This unique approach allowed each floor to be built in only ten days, reducing overall construction time by four months. The highly prefabricated project “consists of 2,116 prefabricated timber elements (362 wall elements, 708 timber-concrete composite units and 1046 posts & beams). This corresponds to around 1,500 m³ of timber (Lennartz, Marc 2025).”

Additional Case Study Buildings

Other key case study projects illuminate the performance enhancements that hardwoods have provided in softwood mass timber products developed in Central Europe. The Tamedia Office Building by Shigaru Ban Architects (2013) is one of the most highly published mass timber buildings in Europe. While many architects are likely aware of the thickened, oval, all-wood joints that have made the project internationally famous, it is in fact the Beech LVL ‘pin’ ovals (Fig. 5) inserted into high-altitude Austrian spruce that allow the friction joint to function (Strehlke, Kai 2024). Another important European product precedent is the development of hybrid species, composite glulam beams with large openings produced by HESS Timber in Germany. The spruce glulam includes Beech LVL intercalated cross-layered plates that significantly increase structural performance and whose apertures allow mechanical ducts and other infrastructure to run through the beam (Fig. 6). The long-span glulam was first successfully used in the International House Sydney building in Australia in 2017. It allowed the architects to keep the ceiling height sufficiently high and the floorplates sufficiently open via the beam's long-span and mechanical-integration capabilities. Aicher and Tapia have thoroughly researched the beams structural performance (Aicher and Tapia 2018). Other buildings that have achieved

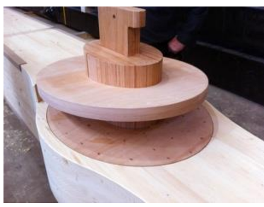



Fig. 5, (left)Tamedia Office Building. Beech LVL oval pin. Photo Credit: Blumer Lehmann.

Fig. 6, (right) International House, Sydney. Spruce glulam with Beech LVL cross layers. Photo Credit: Rensteph Thompson

unique spatial outcomes both aesthetically and structurally using hybrid hardwood-softwood mass timber include St. Josef Parish Church in Holzkirchen, Germany, Finance Park in Stavanger, Norway, King Abdulaziz Center for World Culture in Dhahran, Saudia Arabia, and the Baufeld 1 Suurstoffi Campus in Rotkreuz, Switzerland. Numerous examples of custom hybrid mass timber elements can be found on the company websites of neue Holzbau AG, Blumer Lehman, and HESS Timber as three of the leading mass timber companies in Europe.

Hybrid Mass Timber Production in the United States

"Mass timber products … are widely used throughout Europe, but are now growing in popularity across the United States (Comnick, Rogers, and Wheiler 2021, 1)." As of December 2024, the growth of mass timber use in the institutional, commercial, and multi-family residential sectors is generally tracking an exponential curve in the United States. 2,338 buildings have either been built or are in progress in the United States since 2011 (WoodWorks 2024). Small or limited uses of glulam are not included in this data set. For large structural engineered wood products typically understood as mass timber, the composition of such products is nearly 100% softwood. There are companies in the U.S. that make EWPs from hardwood, such as parallel strand lumber from Weyerhaeuser and niche hardwood glulams from various small producers, for example. Holistically, however, the mass timber market is heavily dominated by softwood products, despite hardwoods accounting for over 40% of American forest biomass. There are few if any large-scale applications of hybrid mass timber in the U.S., and even in terms of temporary full-scale structures, there have only been a few. The Conversation Plinth (2017) by IKD in Columbus, Indiana showcased the architectural potential of hybrid mass timber in the U.S., but due to multi-species lamination/adhesion issues, the temporary structure was dismantled relatively quickly after construction. This project illustrates the technology and/or knowledge gap in multi-species structural product production between the U.S. and Central Europe. Despite a lack of built work in the U.S., researchers have been studying hardwood supply for use in hardwood or HMT products, as well as the difficult processing and grading factors that have limited hardwood utilization in the U.S. (Adhikari et al. 2020; Adhikari, Bond, and Quesada 2023; Espinoza and Buehlmann 2018; Thomas and Buehlmann 2017).

Discussion

Considering that hybrid mass timber products utilize more than just one species of wood, the increase in HMT production and use in the U.S. can diversify the demand on forest resources for more sustainable lumber supply. More research needs to be done regarding the development and production of hybrid mass timber products in the U.S., as well as more research on the implementation and utilization of hybrid-species products in architectural applications in general. Perhaps best exemplifying the current state of hardwood or HMT use for spatially novel buildings in the U.S., the Aspen Art Museum (2014) by Shigaru Ban Architects and KL&A Engineers includes a dynamic, spatially complex notched assemblage of curving mass timber roof elements organized into a 3D space truss. It is a hybrid mass timber system in that the curving birch (hardwood) plywood elements interface with linear spruce (softwood) LVL beams. Notably, the birch plywood and spruce LVL were sourced from Finland, and "the unique structure of the Aspen Art Museum, unprecedented in the U.S., was due entirely to the creative engineering skills of Hermann Blumer of Creation Holz [Switzerland] and Franz Tschuemperlin and Benno Behrendt of SJB [Switzerland], combined with the ingenuity and skill of the timber craftsmen at Spearhead in Nelson [Canada] (Kingsley 2014, 11)."

Industry Maturation

Debatably, the mass timber industries in the United States and Europe are fundamentally different than one another. This could be a product of culture as well as timing, among other factors. The European mass timber market has grown slowly and organically via the well-established network of craftsmen, fabricators, and lumber producers that have a long and storied history in Central Europe. This slow maturation has allowed industrial infrastructure, building regulations, and trade skill to be refined in a manner that supports more diverse product types at more competitive price points, as well as a labor capacity and supportive political will capable of advancing wood construction. While many of the same progressive factors exist in the United States, and the United States also has a rich cultural and industrial history with wood, the mass timber movement has been much more rapid and with a much larger scale of buildings than what has generally been experienced in Europe. Rather than smaller scale, high quality buildings advancing over centuries as in Central Europe, in the United States the mass timber movement began recently and with uniquely large-scale buildings. As such, it is logical that producers of high-performance wood products and building professionals in Central Europe are engaging in perhaps more niche applications of advanced wood products. And doing so at a price point that is approachable for clients, even municipal clients as in the case of the Sports Centre Sargans. Rather than having only a few big companies in the market as in the U.S., the Central European mass timber industry is more diversified and multi-scalar. As such, it is not surprising that the United States is a few years behind when it comes to multi-species mass timber, yet much research progress is being made. As stated in Stefan Torno's interview with Andreas Hirschbuhl of ERNE AG, we must remember that the development process with softwoods was slow too, the products and processes being developed over a long period of time (Torno, Stefan 2021). Further research would be valuable that considers what market share hardwood mass timber products account for in the United States and what specific definition of hardwood mass timber is being used in that accounting process. Additionally, architects would benefit from more case study projects in the U.S. that use hardwood or hybrid mass timber to demonstrate the spatial potential of such products, as well as the regulatory and sourcing hurdles that were overcome to achieve the completed project.

Conclusion

"Currently there is an ongoing dynamic innovation process in the field of wood material and engineering wood products, and the spectrum of EWPs is continuously expanding, reflecting its adaptability and relevance in contemporary architectural practices (Kuzman and Sandberg 2023, 2115)." This study illustrates novel spatial and performative architectural outcomes that have resulted from such material and product developmental processes. It supports the position that novel architectural form and expression in mass timber can be achieved through hardwood-related structural and affective performance enhancements. The study also indicates that the slower maturation of the European mass timber market has positively influenced hardwood utilization in mass timber products. Considering that American architects are privy to very few peer-reviewed publications concerning the aesthetic and structural potential for hardwoods in hybrid mass timber products, this study fills a void in the literature by pairing building case studies with architect and supplier interview data. By focusing on rapid-build assemblies, as well as the material and product contexts that enable HMT utilization, architects are better positioned to specify hardwood-softwood products in practice, thus supporting the creation of unique spatial and structural outcomes.

Educational Context and Acknowledgements

This study was conducted as part of the 'Wood Urbanism' research program at Virginia Tech's campus in Switzerland in 2024. The author's 18 undergraduate students were directly involved with this study as they researched and visited relevant case study buildings and participated in the factory and architectural office visits that underpin this scholarship. The author would like to thank the students and Virginia Tech for the opportunity to conduct the educational program in Switzerland.

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