The Mass Timber Revolution

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Summary

Major changes in construction materials don't happen often, but when they do, they can be transformative. That's why it may seem strange that the latest development in construction materials is a return to a material with a long history: wood, which has been used for thousands of years. Mass Timber—the most recent technological development in wood construction—has roots in the heavy-timber construction used to build mills, heavy industrial structures, and even offices in the 19th and early 20th centuries.[1,2] The materials have since evolved and created new exposures for insurers—and new opportunities.

What is mass timber, and why should insurers care?

Sakyamuni Pagoda, Yingxian County, China

Construction industry professionals define mass-timber materials as a type of engineered wood product made by affixing or gluing together many pieces of wood veneers, flakes, or dimension lumber to form larger, stronger pieces such as panels and beams.[3] The term "engineered wood" has been used for a variety of derivative or composite wood products, such as plywood or particleboard, made by bonding together a variety of wood fibers, flakes, or veneers[4], while dimension lumber is building lumber cut to standard or specified sizes[5], such as a two-by-four (width and depth). Mass timber construction is the construction style that uses these large engineered panels and beams to form the primary load-bearing structure of a building.

From an underwriting standpoint, mass timber doesn't fit easily into any of the construction classes used for decades in the insurance industry. It challenges the long-standing assumption that combustible materials aren't suitable for tall buildings. Because mass timber is so new, little statistical data exists to help develop rates. And since fire is often the chief property peril that underwriters consider, timber's combustibility only adds to the imperative for the insurance industry to gain a better understanding of this new construction type.

Insurers must consider many things when evaluating mass timber construction, such as the different property characteristics and risk factors that mass timber brings to a building.

The history of mass timber

For centuries, the basic construction components were wood, stone, iron, and masonry. Inexpensive mass-produced steel and concrete in the latter half of the 19th century revolutionized the way buildings were designed, allowing architects and designers to build taller and taller buildings. Those materials became synonymous with the urban environment.

Throughout the 20th century, the modern city and its skyline developed, replete with concrete sidewalks, roads, and gleaming steel-and-glass skyscrapers. Wood was relegated to homes and small commercial buildings.

Although heavy timber is no longer commonly used for mid-rise urban office buildings, tall wood buildings aren't a new concept. The *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada,* a resource on architectural and building code considerations of mass timber, says: "Tall pagodas in Japan were built 19 storeys high in wood 1,400 years ago and are still standing today in high-seismic and wet-climate environments. In the Maramures Region of Northern Transylvania, the 56-meter (184-foot) Barsana Monastery has been standing since 1720."[6]

Mass timber differs from frame construction because it uses large engineered wood panels as opposed to light wood stud framing elements, which are typically single pieces of dimension lumber used as floor, roof, or wall supports (see Types of Mass Timber, page 14).

Mass timber shares some similarity with the historic heavy timber or "mill" style construction common in the late 19th and early 20th centuries. Mill construction used large, solid-sawn timber pieces as structural elements with stone or masonry walls. The large wood members in heavy timber can have size and fire-resistive properties like those of mass timber. However, mass timber is much stronger than heavy timber because the many individual pieces comprising a mass timber panel compensate for weakness in any single piece, such as knots in the wood.

Barsana Monastery in Maramures, Romania

Mass timber can be combined with other structural materials which, for the purposes of this article, we'll call hybrid mass timber construction. This incorporates mass timber structural elements (such as floors, walls, or roofs) with traditional noncombustible materials like concrete and steel. Although the wood industry and some environmental advocates are marketing mass timber as a total solution, hybrid construction may be the most common near-term method for wood high-rise buildings while the technology takes root. That's due at least as much to current building codes as to the structural and fire protection properties of each material. For example, the tallest wood building in the world—an 18-story college dormitory in British Columbia, Canada called Brock Commons—combines mass timber framing and floor slabs with a concrete core that houses exit stairs and elevators.[7] The concrete core helped gain code approval for fire safety purposes[8] and helps in lateral support for the wind load of the building[9], while the mass timber columns support most of the building's weight.[10]

Current developments in mass timber

Because of its versatility, architects and builders can use mass timber in a variety of structures, from low-rise office buildings and residential structures, to sports arenas like the Richmond Olympic Oval in British Columbia[11] and a proposed multipurpose indoor arena at the University of Idaho.[12] However, the most fascinating development is its potential for tall buildings. These have been the exclusive domain of concrete and steel, especially after building code changes in the 1920s and 1930s limited the height of combustible construction.

While there's no standard definition of tall wood buildings, we'll use the term to describe buildings taller than what's currently permitted by local building codes for wood construction, such as wood frame (class V) or heavy timber (class IV) construction. That's typically four to six stories in North America. New Jersey,[13] California,[14] and New York[15] building codes all permit a maximum height of five stories for a Class IV office building, three stories for Class V, and one additional story if the building is sprinklered. In New York City, the limitations are similar, except unsprinklered class IV structures are permitted to be six stories, seven if sprinklered.[16]

The regulatory environment for mass timber is beginning to evolve. At present, all tall wood projects in the United States require special code approval, a time-consuming and expensive process. That may soon change. The International Code Council (ICC) is the body primarily responsible for drafting the International Building Code (IBC), the model building code used by virtually all jurisdictions in the United States.[17] The organization recently formed an ad hoc committee to investigate code changes to allow taller wood construction without special approval. Changes to model codes could come as soon as 2018,[18] although adoption by local jurisdictions could take longer.

Pyramidenkogel observation tower in Austria

Some examples of current mass timber construction

As noted earlier, the tallest wood building in the world is the 18-story, 174-foot-tall Brock Commons student housing for the University of British Columbia, completed in 2016. The floors are made of cross-laminated timber (CLT), while the columns are parallel strand lumber (PSL) and glue-laminated timber (GLT, or glulam). The elevators and emergency stairs are enclosed in a concrete core in the center of the building, and the cladding is 70 percent prefabricated wood fiber.[19]

The world's tallest wood structure is the 328-foot-tall Pyramidenkogel Observation Tower in Austria, completed in 2013. The primary vertical support is provided by 16 continuous glulam columns, while lateral support and stiffness are provided by steel rings and struts.[20] The three observation decks are CLT.

In the United States, the tallest completed wood building is T3, a 7-story, 238,000-square-foot office building with ground-floor retail in Minneapolis, completed in 2016. The elevator core, foundation, and first floor are concrete with glulam post-and-beam construction elsewhere and nail-laminated timber (NLT) floor plates[21] with steel cladding.

All the buildings noted so far are the "hybrid" style described earlier. There also are numerous mid-rise examples of all-mass-timber construction in Europe, but development in the United States has been slower. Framework—a 12-story, 148-foot-tall, 90,000-square-foot office building with a CLT floor and core system and glulam columns—is the first all-timber high-rise approved in the United States.

Why mass timber?

Why is there a push to adopt mass timber construction, especially when concrete and steel are so successful? In addition to being much stronger than traditional wood when it comes to structural capacity, there are several reasons.

The first is that construction costs are expected to be lower with mass timbers as the technology matures. Bernhard Gafner of structural engineering firm Fast + Epp, says that, in his firm's experience, a mass timber project is about 25 percent faster to construct than a similar project in concrete. Noting the advantages for urban infill sites, he says it also offers 90 percent less construction traffic and requires 75 percent fewer workers on the active deck, making for a much quieter job site.[22] Fewer workers could mean lower installation costs, and faster construction times usually mean earlier building openings—all of which increase revenue for project owners and developers. Using prefabricated panels generally reduces the number of tasks construction workers perform, which also may improve worker safety.

Second, mass timber is often more environmentally friendly than many traditional building materials. The push for using sustainable resources—in particular, green-certified (LEED) construction—has helped ignite interest in mass timber for taller buildings. Wood is a sustainable resource like any plant, and it has a smaller carbon footprint. Wood stores carbon, which is about 50 percent of its dry weight.[23] When wood decomposes, it releases the same amount of carbon back into the atmosphere, making it carbon-neutral. In contrast, both steel and concrete emit a large amount of CO_2, and these materials don't store carbon. In fact, concrete production represents more than 5 percent of world CO_2 emissions.[24] For similar volumes, mass timber requires 5 times less energy to produce than concrete and 24 times less energy than steel.[25]

Sustainable logging also has environmental benefits. Responsibly managed logging will sustain the availability of wood for future generations, whereas steel and concrete are finite resources. Also, steel and concrete mining takes an environmental toll at the point of extraction, whereas sustainably managed forests can be beneficial to local ecosystems.

Finally, there's huge economic potential for the lumber industry in large forested areas, such as the Pacific Northwest in the United States and Canada. Areas rich in forests that can supply wood for mass timber could see an economic benefit in advancing mass timber construction. For example, Oregon is investing hundreds of thousands of dollars to promote mass timber to revive its lumber industry and add manufacturing jobs.[27]

Since most advanced mass-timber manufacturing currently takes place in Europe or Canada, the potential increase in demand could create opportunity for more U.S. producers. Local sourcing and manufacturing are requirements for green building certification. The U.S. Department of Agriculture, supported by lumber trade groups, is receptive and sponsors the U.S. Tall Wood Building Prize Competition. The competition awards research and development funding for wood construction.[27]

Underwriting implications

Risk factors to consider when underwriting mass timber include:

Source of material: Problems with drywall manufactured in China several years ago, highlight how manufacturing standards can significantly differ between countries. Underwriters should know about two international standards: ANSI/APA PRG-320 is the standard for CLT performance recognized by the IBC, and ANSI/AITC A 190.1-17 applies to glulam.[28] While sourcing from overseas may be less likely due to both the supply of timber in North America and the environmental cost of shipment (LEED certification prefers local sourcing[29]), underwriters should consider making sure materials comply with these standards.

Moisture content: Wood absorbs or loses water from the atmosphere, depending on surrounding air conditions. That can cause it to shrink or expand as much as 2.5 percent in common air and humidity conditions.[30] That is less of a concern in short frame structures but can be a major concern in tall buildings because the percentage change is amplified. A 30-foot-tall building that shrinks 1 percent would lose about 3.5 inches, while a 300-foot-tall building would lose 3 feet.

Expansion or shrinkage during construction could cause delays or structural problems after construction. Thus, it’s important to let mass timber reach close to its equilibrium moisture content (EMC)—the point where it won’t expand or shrink—before installation.

Underwriting analysis could consider the moisture content of the mass timber when manufactured; its EMC where it will be used (which depends on climate); protection of the mass-timber panels during shipping, storage, and at the jobsite; and weather conditions during construction. Construction sequencing is also important, as any construction materials that need to be applied wet, such as concrete, can influence the wood size if applied directly to wood.

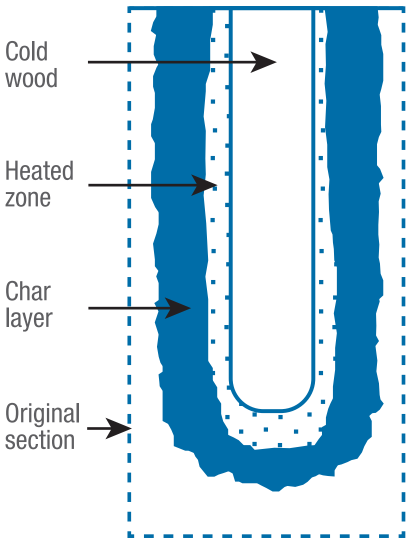
Mass Timber used in support beams for a church under construction.

Fire: The IBC defines fire-resistance rating—an important concept in property underwriting—as how long "a building element, component, or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both."[31] A two-hour fire rating of structural materials, floors, and exterior walls is a code requirement for tall buildings up to 11 stories in the IBC model code and analogous to ISO-6 construction. For skyscrapers above 11 stories, three hours of fire resistance is required.[32]

Light frame construction ignites at 500 degrees—a primary reason it isn't used to construct buildings taller than four stories. Heavy timber has some fire-resistive properties, and the same is true for mass timber. Thick wood beams (1x1 foot for structural beams) are hard to ignite fully; they char instead. Charring is incomplete combustion: the surface wood burns, but the whole piece does not combust and will self-extinguish if there is no other fuel. The char rate of wood is 0.025 inches per minute, or 1.5 inches per hour.[33] The char layer acts as an insulator, keeping the wood underneath cool and maintaining the load-bearing capacity of the uncharred wood.

In part because of this, mass timber solid-wood structural elements, such as CLT, glulam, and so forth, have been designed to perform at a two-hour fire-resistance rating, as in the all-wood Framework building.[34] One test even showed a 5-ply CLT panel lasting over 3 hours in a standard, 1800-degree fire test environment.[35]

The bad news is that charring wood will add fuel to the fire and increase the heat and smoke output relative to noncombustible materials. For this reason, encapsulation (exposed wood covered in fire-resistive materials) is used on many tall wood buildings built so far in North America. The *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada* states:



> **"It can be demonstrated that complete encapsulation of all mass timber elements can result in an equal or better level of fire performance than that provided by buildings of noncombustible construction."**[36]

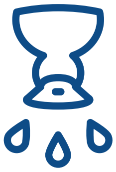
For these reasons, underwriters may want to consider the fire-resistance rating of the mass timber used and whether it's encapsulated. Although fully encapsulated timber has generally been used so far in North America, the trend may be toward less encapsulation for future projects as architects and tenants may want to leave more wood exposed for aesthetic reasons.

Grenfell Tower tragedy, London, 2017

While the science of mass timber and encapsulation of mass timber is still being established, the location of the exposed wood for partially encapsulated (or un-encapsulated) construction may be another important underwriting consideration, since the exposed wood adds to the combustible load, and may create a greater risk to health and safety. This is true especially if the exposed timber is located in egress areas, like stairs and elevators, since the wood could char in a fire, increasing the smoke and heat, and hindering the ability to escape or firefighting efforts. Due to these factors, underwriters may want to pay attention to exposed timber in ingress/egress areas, concealed spaces, and other spaces where it could present unusual exposures.

For many other interior spaces, exposed wood may be appropriate. Mass timber has a lower flame-spread rating than many common decorative interior finishes, including architectural woodwork and paneling, some wallpaper and carpet, and vinyl and textile wall coverings. Mass timber is considered a Class B material with a flame-spread rating of 35–40. For reference, the flame-spread scale starts at zero for brick; normal wallboard has a flame spread rating of 15–20; and wood typically used in architectural woodwork has ratings greater than 100.[37] Flame-retardant treatments for mass timber that lower flame spread are also available. In general, underwriters may want to ensure that flame-spread ratings of interior walls, floors, and roofs of mass timber buildings are consistent with those of buildings of more traditional construction.

Given the June 2017 tragedy at the Grenfell Tower in London, where newly installed combustible cladding contributed to the spread of a fire that eventually destroyed a 24-story apartment tower,[38] building cladding is another concern for underwriting for all buildings. Most building codes in the United States already require noncombustible cladding for tall buildings, but as awareness of mass timber as a cheaper, green alternative increases, insurers may want to place extra emphasis on the type of cladding used for mass timber construction.



Sprinkler systems: Enhanced sprinkler protection for areas of exposed wood may also need evaluation. Concealed spaces (such as between walls or above drop ceilings) or mechanical spaces (where plumbing and wiring are hidden) are typically left unsprinklered in noncombustible buildings if there's no fire load. With mass timber construction, sprinkler protection of these areas and additional smoke detection may be important, depending on the level of encapsulation and placement of fire barriers.

Vertical spaces, such as elevator shafts, need protection too. Water supply and maintenance of sprinkler protection are paramount. The *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada* recommends redundant fire pumps, an on-site water supply, and full encapsulation of timber in concealed spaces.[39]

Wind and earthquake: Mass-timber construction is substantially lighter and more flexible than concrete and steel, giving it inherent advantages in wind and earthquake performance.[40] It is also stronger pound for pound than concrete or even steel; glulam has a strength-to-weight ratio over 3 times higher than concrete and almost 30% higher than steel. For Framework, the tallest all-wood building approved in the United States, seismic performance was an important concern given its location in Oregon. Tests on massive shake tables at Portland State University and Oregon State University validated the building's all-timber structural design[41] and were a key factor in gaining approval.

Wood's light weight and flexibility make it ideal for areas prone to high wind.[42] However, as buildings get taller, individual design is the most important factor for wind and earthquake, and a combination of flexibility and stiffness is desirable. Significant research into seismic and wind performance is underway, and insurers should consider the construction of the building's core and the connections between wood members for appropriate stiffness and flexibility.

Water damage: As mentioned earlier, wood absorbs water, and rot can seriously impair wood's performance. Integrity of exterior cladding, maintenance of the building, and the placement and maintenance of plumbing systems and bathrooms are key factors with respect to these perils. Numerous water-resistant coatings are available, and underwriters may want to focus on whether such coatings have been applied to timber in exposed areas most prone to water damage.

Underwriters may also want to consider if extra care was taken during mass-timber building design and construction to address water-related concerns and water's long-term effects on areas not usually subject to water damage, such as floorplates and interior structural components of high-rises. These areas are more vulnerable if they are made of mass timber. For example, long-term seepage from plumbing that goes unnoticed could impair the structural stability of a mass-timber building if structural supports rot, or sprinkler leakage could cause significant damage to untreated mass timber. Little data or analytics exist about the long-term performance of mass timber heavily exposed to that type of water condition, but underwriters may want to consider whether mass timber is desirable in areas, like foundations, with the highest exposure to water damage.

Mold and fungus: Invasive mold growth in buildings is a well-known risk to occupant health. Wood supports mold growth, and mold will grow if the relative humidity remains at or above 80 percent for a sustained period, even without the presence of other water or moisture sources.[43] Decay-causing fungus also can colonize wood at very high moisture contents, and is a risk to structural stability if allowed to proliferate. Due to these factors, insurers may want to consider the average humidity of an area when mass timber is used and avoid extremely humid areas. Sealants and preservatives can minimize or even prevent fungus proliferation, and insurers may want to ensure that they have been applied to all mass timber. Underwriters may want to pay attention to building maintenance practices, as a good maintenance program can help avoid mold and fungus problems.

Insects/pests: Wood is susceptible to termite damage, and termite control has long been a factor in wood frame construction. Insurers may want to make sure the same steps are taken in a tall wood building as in a conventional frame building, especially in areas with a known exposure to termites. Underwriting considerations could start during site management, such as soil treatments that can create a chemical barrier to termites. Mesh foundation wraps can protect against intrusion, and concrete foundations also protect against termites.

Insurers also may want to ensure that wood cladding, if used, is placed high above the soil and coated to prevent termite infiltration, and that mass timber structural members are not placed in direct contact with soil. In situations where some contact with soil is possible, underwriters may want to make sure that wood treatments that kill termites have been applied. Again, building maintenance can also impact termite exposure.

Wood adhesives: Wood adhesives used in the laminating process are a concern unique to mass timber. Formaldehyde, an irritant and carcinogen, is used in many adhesives, and different types have varying levels of chemical stability that reduce or increase emissions of volatile organic compounds under certain environmental conditions. That can affect worker safety during construction, with formaldehyde being released during sawing work. Fortunately, the adhesives most commonly used in structural-quality mass timber—phenol formaldehyde, resorcinol formaldehyde, phenol resorcinol formaldehyde, and melamine formaldehyde polymers—don't chemically break down in service and no detectable formaldehyde is released.[44] Builders shouldn't use adhesives with urea formaldehyde, one of the more volatile compounds, in any laminations.

Replacement costs: Reconstruction-related costs and building reuse after a loss are factors in underwriting mass timber buildings. For example, if a partial loss from a fire occurs and structural mass timber members are partially charred, will that building be suitable for re-occupancy the way a similar noncombustible structure would? Will it take longer to repair buildings because of damage to mass timber structural members, or will they have to be demolished, while a similar noncombustible structure could be repaired?

These concerns can potentially affect coverages such as business income and ordinance or law. Replacing charred or otherwise damaged structural members may have enormous costs. However, that can work both ways: wood might suffer more damage from fire but less damage from other events. such as earthquakes.

Long-term mass timber performance: While mass timber is a relatively new construction concept in the United States and most types of mass timber discussed are recent developments, glulam has been in use since the late 19th century in Europe, although early glulam differs from modern types in manufacturing processes and adhesives used. Many examples of buildings constructed with glulam are still standing, including the former Hygiene Institute, Zurich, built in 1911, where a bell-shaped roof dome remains a prominent feature, and the glulam railway platform canopies in Interlaken-West (Switzerland) and Erfurt (Germany), both dating from 1913, which also remain in service.[45]

Examples of these long-surviving tall wood buildings provide clues about the long-term durability of mass timber, but more research and data analysis must occur before we draw any definite conclusions. Even structures that have withstood the test of time are not impervious to the ravages of flames. In December 2017, the 16-story Lingguan Mansion pagoda in Mianzhu City, China—built during the Ming Dynasty (1368 to 1644 AD)—was reduced to ashes. The tower had been badly damaged during the 2008 Sichuan earthquake and was restored, but much of the complex was still under construction at the time of the fire. The Buddhist holy site had been the tallest wooden structure in Asia.[46]

Conclusion

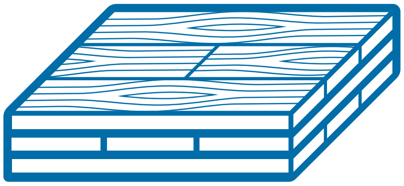
Glulam construction bridge

In an area of construction as new as mass timber, it's difficult to list all the considerations underwriters must make. Mass timber challenges many old assumptions regarding combustible materials in taller buildings. Economic and environmental forces are driving mass timber into mainstream use. The insurance industry needs to take a proactive approach to understand mass timber's strengths and weaknesses compared with more traditional construction. Mass timber has arrived in the United States and may soon be used to construct a high-rise or even a sports arena near you. With its versatility and abundant supply, mass timber could dominate new construction in some areas and mean larger book growth for insurers willing to write it.

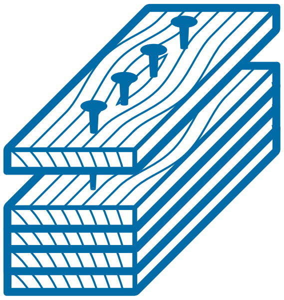
So, are you prepared to profitably insure mass timber construction?

Types of Mass Timber

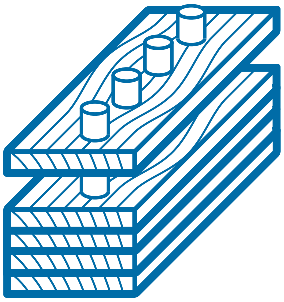
There are several different types of engineered mass timber products on the market today under various trade names. They're generally categorized by the way the lumber is bound together and the types of lumber included in the product. By interlocking many pieces together, builders can create large panels and beams. Here are the different types:



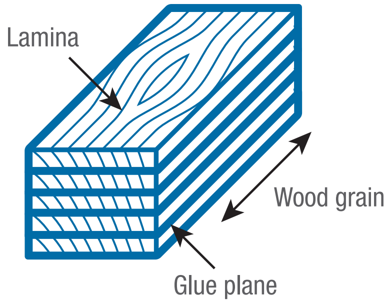
Cross-laminated timber (CLT)
is a wood panel consisting of several (usually 3, 5, or 7) layers of dimension lumber oriented at right angles to one another and glued together to form structural panels. CLT is used for floors, walls, and roofs.[47]



Nail-laminated timber (NLT)
is created by layering individual pieces of dimension lumber together, usually on edge, and fastening with nails to form one structural element.[48] These panels are typically used for floors, decks, and roofs.

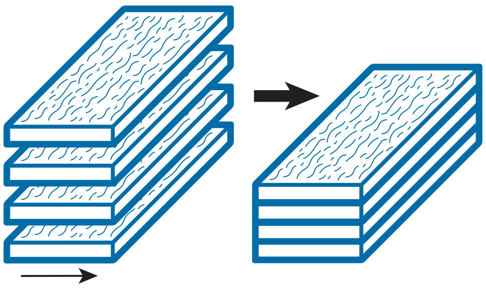


Dowel-laminated timber (DLT)
panels are like NLT except they're fastened together with hardwood dowels[49] and made of softwoods, such as pine or spruce. The friction fit of the dowels adds dimensional stability. DLT is the only mass timber product that doesn't use glue or nails and is ideal for acoustical applications.



Glue-laminated timber (GLT, or glulam)

is similar to NLT and DLT except that the dimension lumber is glued together under pressure. The lumber is chosen and positioned in the panel based on its performance characteristics for the beam's use.[50] GLT is used for load-bearing beams or columns. It's two-thirds the weight of steel and one-sixth the weight of concrete for similar strengths.[51]



Structural composite lumber (SCL)

is a family of wood products created by layering dried and graded wood veneers, strands, or flakes with moisture-resistant adhesive, molding them into blocks, and sawing them into specified sizes.[52] Types are laminated veneer lumber (LVL), laminated strand lumber (LSL), and parallel strand lumber (PSL). They're used as load-bearing beams or columns.

Mass timber construction does not include:

light frame construction— buildings constructed with light wood structural members

heavy timber construction— primary structural members made of solid-sawn timber

(mass timber construction can include some heavy timber, but the majority should be mass timber)

joisted masonry or any of the other "noncombustible" construction types

(some mass timber products are rated to perform just as well in a fire)

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