PLANT A SEED

Designing with wood and biobased materials.

Henning Larsen

Content

We define beauty by the lasting impact of our design.

Photo by Rasmus Hjortshøj

Rethinking our carbon footprint.

40% of global emissions are associated with the construction industry, with pre-construction phases accounting for a staggering 11% of them. Referred to as upfront carbon, these phases include extraction, production, and transportation of materials.

Uncomfortable as the numbers may be they also reveal the potential our industry has to be at the forefront of real and tangible change. To us, this means embracing the opportunities to reduce our footprint, seeking scalable solutions to decarbonize the industry.

In other words, it is increasingly important to reconsider the materials of our craft. Wood and other renewable bio-based materials offer great alternatives.

Trees absorb carbon dioxide throughout their lifetime and release it in decay. As such, timber construction can help to reduce the amount of carbon dioxide in the atmosphere by prolonging the carbon cycle. This means mindfully considering the many individual scales at which we interact with wood, from tree trunks and bark to cross-laminated timber, woodchips, fibers, and even paper.

With circularity and ‘cascading use’ as clear priorities, we must extend the material life cycle of wood and draw out its capacities for carbon storage. Timber is also far lighter than other building materials and is thus much easier to transport. Compared to concrete, it requires up to 5 times fewer transportation carriers!

With this handbook, we aspire to raise awareness of all the benefits that come with incorporating more biogenic materials into architecture, sharing our knowledge from projects in Scandinavia, Germany and France.

8 reasons to build in wood

In the European Union, the average greenhouse gas emissions per capita is 8.7 tons per year. This means that an average school built in wood stores as much CO_2 as 115 people emit over a one year period.

Source: Eurostat

1. Wood reduces the carbon footprint of construction.

Wood and other organic materials are the only construction materials that can store carbon dioxide and therefore have a negative CO_2 balance in production, even after accounting for the energy required in processing. Concrete and steel, in comparison, have many times the CO_2 emissions of wood structures. While recycling these products improves their carbon footprint, only timber has the ability to store it.

Sources: Metsawood and KBOB Switzerland

2. Technically, timber is renewable.

Timber milled from sustainable forestry – for example, FSC or PEFC certified – is the only major structural material that is technically, completely renewable. Globally, there is more timber supply to meet an increase in demand. The growth rate of European and Northern American forests, for instance, far exceeds the rate that it is currently harvested.

Sources: Dansk Skovforening, proHolz Austria

3. Timber structures are faster to build.

Building in wood can save approximately one third of the building time used in conventional concrete structures. The building is weather-tight upon installation of the prefabricated wooden structure and as there is no drying or hardening time required, the interior can be installed immediately after. Prefabrication frees the construction process from the uncertainty of weather events and allows for easy construction even in winter months.

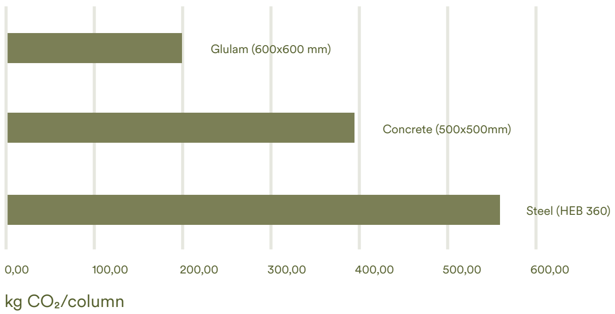
Source: Wood Supply (www.wood-supply.dk

4. Done right, wood can be very cost effective.

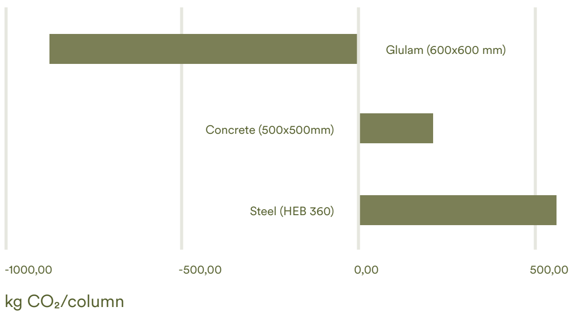
There is no reason building in wood should be more expensive than conventional structures. In particular, the shortened construction time of prefabricated wood structures reduces the overall building costs. In addition, the walls and ceiling surfaces do not require an extra layer of finish because wood can be directly exposed. As a light structural material, wood can achieve higher structures on weaker ground with less foundation.

Source: TU Bygg Norge

Sum of emissions from production and end of life:



Emission from production:



Comparison of columns of different materials with the same function and strength.

The calculation compares the carbon emissions during production and end-of-life of a 4 meter column of similar strength and fire class.

The graph on top accounts for both the negative CO_2 sequestered in the production (growth) of the timber but also its release again in the end-of-life scenario. It is highly likely that the future holds other possibilities than combustion of wood and will allow for complete reuse and recycling, improving the carbon balance of the timber even more.

The graph on the below indicates the CO_2 emissions from the production phase alone, with the glulam column indicating a negative impact, which is the sequestered CO_2 in comparison to the steel and concrete columns which emit CO_2 in the production phase.

Sources: Calculation based on current Ökobau data (steel, concrete) and on EPD data from the Danish Timber Information Assoc.

5. Wood is a safe material.

Buildings with wooden structures are just as safe as concrete or steel structures. Far from being an unpredictably flammable material, wood has a calculable burn time and innate flame retardant properties. Cross laminated timber (CLT) burns at a rate of 0.65 mm/min, which can be used to calculate the necessary thickness of structural elements. The char layer formed on wooden surfaces actually slows the combustion process down and does not need extra treatment to withstand collapse from fire, whereas steel quickly starts to deform under heat, and concrete collapses without warning.

Source: StoraEnso

6. Timber has many health benefits.

And living in a home built in organic materials improves overall health while exposing residents to significantly less toxins than conventional home building materials.
Exposure to wood has proven to relax heart rates and can improve the recovery and healing times of ill people. Studies show that school children's heart rates are lowered by 8,600 beats per day in classrooms with wooden surfaces. The naturally occurring antibacterial effect of wood brings an additional hygienic advantage to its mental wellness benefits.

Source: Research of TU München with Proholz Bayern and Human Research Austria

Photo by Rasmus Hjortshøj

Photo by Rasmus Hjortshøj

7. Wood opens up the door to new design explorations.

Building in wood offers unique design possibilities due to the combination of aesthetic and structural qualities of the material. Timber not only has strong environmental advantages but also has produced a design movement of its own. The sheer variety of wood species allows for endless opportunities. Timber architecture creates elegant structural solutions that can be admired in both standardized and free-form architecture.

8. Timber is a sensory experience.

Wood is a natural material that provides a complete sensory experience to architecture. Wood has the ability to stabilize moisture; a study showed a reduction of 63% in the peaks of indoor air humidity values. Its distinctive qualities of warmth, tactility, and its characteristic smell is almost universally appreciated. With the ability to regulate the humidity in a room, wood also improves indoor air quality and climate. Timber architecture bridges the gap between the natural and built world while creating a sustained connection with nature in daily life.

Source: Wood Products (www.woodproducts.fi)

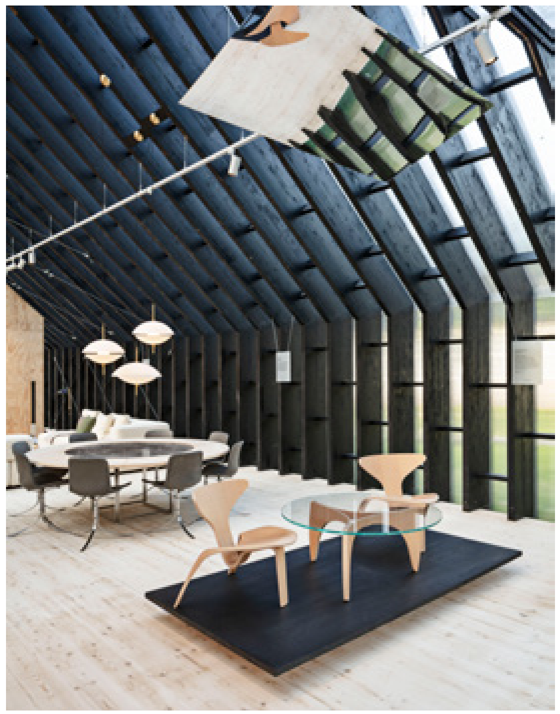


Photo by Laura Stamer

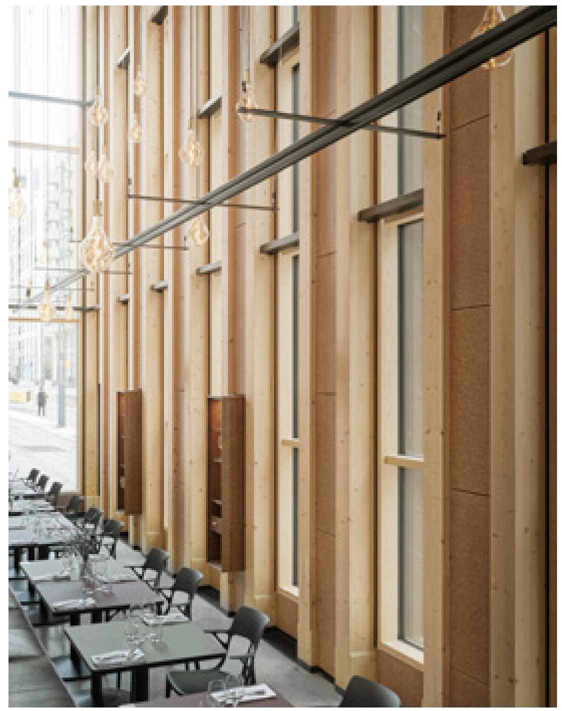


Photo by Emil Fagander

Debunking myths about timber construction

Wood is not made for this climate; it will rot.

FALSE There is no reason not to build in wood in temperate climates, nor any other climate. The appropriate type of wood is used in each unique situation, according to rules of craftsmanship that guarantee the longevity of the structure. The lifespan of wood in dry conditions is virtually unlimited, while lasting for decades even in outdoor conditions. Studies have proven that wooden cladding can withstand Norwegian weather for up to 60 years, if correctly applied.

Source: Levetid for tre i utendørs konstruksjoner

Wood is not strong enough.

FALSE Wood has an excellent strength in relation to its low weight, making it a suitable construction material for most applications, especially on tension.

Wood is dangerous because it burns.

FALSE Wood burns but it can be controlled. As with any other type of structure, wooden buildings must fulfill all fire safety require-ments, meaning that people, animals, buildings and goods are protected against danger or damage. The charring of wood slows down the burning process and, where necessary, the timber parts can be encapsulated to protect them.

Building in wood is too difficult.

FALSE It might seem more difficult to build in wood at first but this is primarily due to a lack of exposure and experience compared with other traditional building materials. Building in wood is just as feasible as with any other material. Timber construction experts already exist to consult on projects, and as this material becomes a normalized part of the architecture industry's lexicon this barrier will be significantly reduced.

Wood is not sustainable, as forests are cut down.

FALSE More forests are regrown in Europe than are felled. Just 62% of the yearly gains in wood mass in European forests are milled. The choice to build with certified wood (e.g. FSC) guarantees that only wood from sustainable forestry is used.

Source: State of Europe's Forests 2015
by Forest Europe growing life

Wooden buildings covered in gypsum and other materials don't make sense.

FALSE How much wood is exposed in a structure is mainly an aesthetic conside-ration. Though fire safety standards may require the use of fire protective layers, such as gypsum, this does not diminish the advantage of building with wood. Concealed timber structures maintain all the benefits of exposed wood, including reduced carbon footprint, reduced construction time, and improved indoor air quality.

Building in wood is too expensive.

FALSE Although the planning period of a timber building may take longer, the time saved due to efficient construction techniques eliminates the price difference.

In a life-cycle perspective, all wood is burned at end-of-life.

PROBLEMATIC Burning is the default scenario for wood building materials today, resulting from the "+/- rule" that all captured carbon must be released at the product's end-of-life. This is the basis for life-cycle calculations today. This linear consumption of goods is being challenged by many in the industry who advocate design for disassembly, thereby promoting direct reuse of valuable resources.

Inspiration

BESTSELLER

Lelystad, Netherlands | 155,000 m² | 2023–2026

Located in Lelystad, on the Dutch island of Flevopolder, our design for BESTSELLER's Logistics Center West (LCW) honors the area's surrounding landscape, which is characterized by wetlands and forests.

Built primarily of mass timber, straw, and other biogenic materials, the building aims to maximize resource use, minimize waste, and increase biodiversity.

To create an atmosphere that prioritizes employee well-being and enables a range of functions across scales, our design emphasizes flexibility and the integration of nature into the workspace. Abundant natural light will flood the timber interiors, enhancing focus and improving efficiency.

Opportunities for employees to interact with the natural world have been created throughout the design. These include the building's roof, as well as a boardwalk meandering through the artificial wetlands. Incorporating plant identification, informative diagrams, and seating areas in and amidst nature, this space will serve both as a scenic route and an educational experience. Other areas will be off limits to people, protecting delicate ecosystems from human impact.

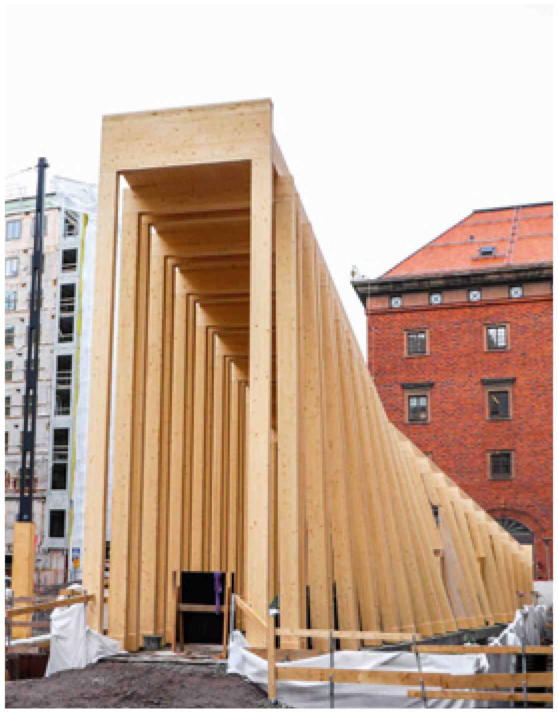
Renders by Aesthetica Studio

RUMMEL RESTAURANT

Stockholm, Sweden | 500 m² | 2020–2022

Nestled in the streets of Stockholm is restaurant Rummel, a 500 m² timber building carefully crafted with disassembly in mind. Enabling flexible usages and a prolonged life cycle of its parts; the building design embraces temporality, demonstrating that everything – including our built environment – is in a constant state of becoming.

With a burnt wood exterior and glulam frames, Rummel's timber structure is designed with changing angles and heights, forming the building's irregular shape. With an architectural gesture that found its inspiration in the neighborhood's collage of older, low-lying buildings and newer, high-rise constructions, the 500 m² building progresses from a height of 10 meters on one end, to 4 meters on the other.



Render by DPI Studio

Photo by Emil Fagander

Photo by Rasmus Hjortshøj

Photo by Helene Mikkelsen

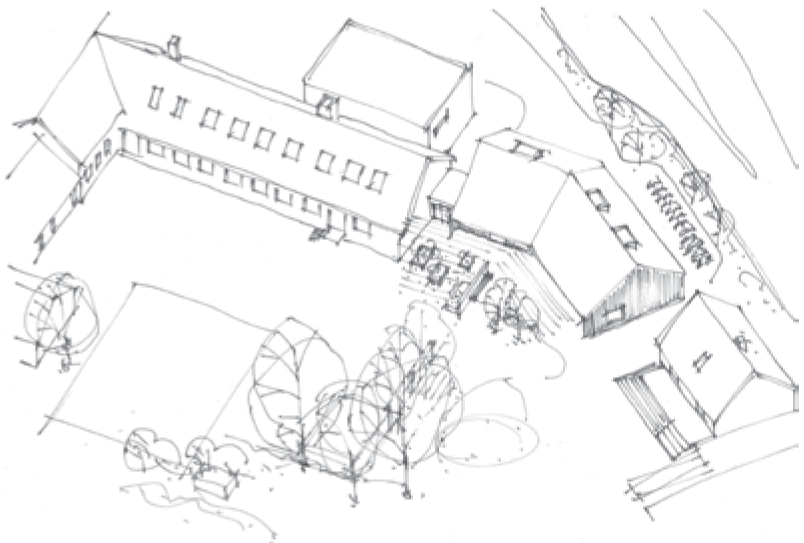
FELDBALLE SCHOOL

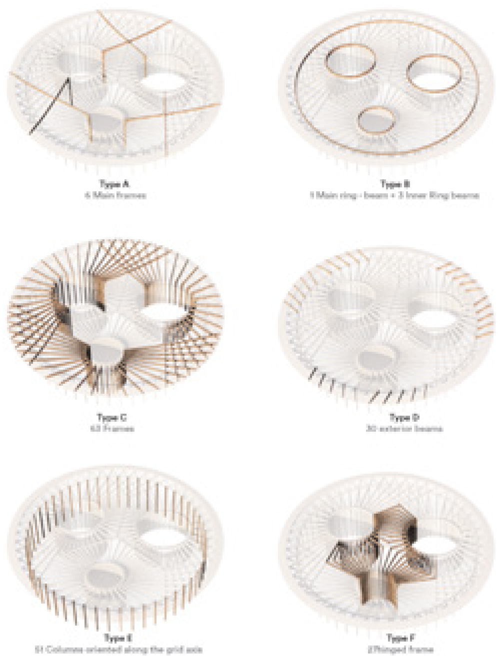
Rønde, Denmark | 250 m² | 2019–2022

Designed for a generation coming of age with the burdens of climate change, the 250 m²/2,700 ft² extension of Feldballe School, acts as a scalable example for designing with carbon-sequestering biogenic materials.

An exciting testing ground and incredible opportunity to push our decarbonization agenda, this project allowed us to explore ways of designing a building that could truly harness the natural carbon cycle. We chose to radically rethink our choice of materials, turning to wood, seagrass, and straw. Locally sourced, natural, and bio-based, they have proven themselves viable alternatives to conventional materials.

In selecting materials that naturally absorb and store CO_2 in the carbon cycle, not only did we generate immense carbon savings, but we successfully designed a structure that is composed of carbon sequestering elements. These elements are completely free of toxic chemicals, fire-safe, and once assembled, offer efficient insulation as well as – according to students and teachers – a noticeably improved indoor climate. With circularity and waste management in mind, the structure is designed for disassembly and reuse, offering flexibility, ease of repair, and making it possible to reinstall or recycle its parts in the future.





WORLD OF VOLVO

Gothenburg, Sweden | 22.500 m² | 2019–2024

The design of World of Volvo integrates computational parametric design and timber as the main structural element to provide the backdrop for thriving native landscapes and a warm invitation to experience 'the right to roam.'

The use of timber in World of Volvo embodies a return to a most traditional of building materials in the Scandinavian context but does so through decidedly modern methods and approaches.

A flexible computational workflow integrated from the very early phases made it possible to experiment with the height of the building, the geometry of the roof, the radius of the three inner circles, and the number of columns, while evaluating the structural implications of these choices together with the manufacturer.

This advanced digital collaboration resulted in decisions that are informed by the material itself, allowing us to optimize material use without compromising on the concept.

Photos by Rasmus Hjortshøj

Render by KVANT-1

FÆLLEDBY

Copenhagen, Denmark | 181,000 m² | 2019–2031

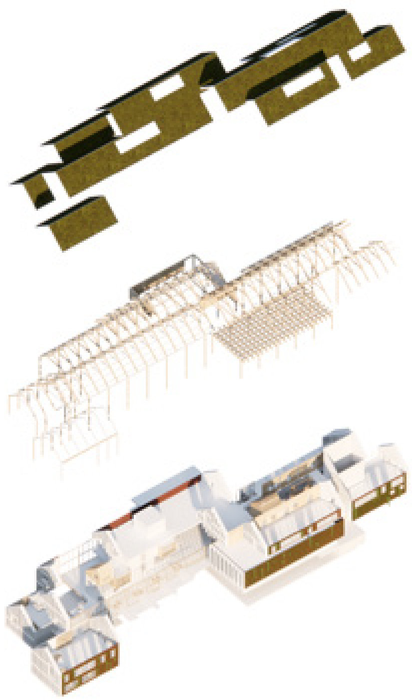
Copenhagen's first all-timber neighborhood, Fælledby brings the urban environment into harmony with existing natural landscapes, establishing a community of ecologically responsive housing units organized according to the model of a 'rural village'.

Faced with the challenge of accommodating a growing urban population while preserving the area's natural landscapes, our design for Fælledby envisions a progressive neighborhood on land that was once used as a dumping ground.

80% of the construction materials will be timber, and with low-rise buildings intended to house 7,000 residents as well as a school, a daycare center, an elderly home, and retail shops, the design rethinks the boundaries of a city's conventional urban development by embracing the natural ecosystems that exist on its fringes.

Renders by Vivid-Vision

Photo by Rasmus Hjortshøj



UNIVERSITY OF FAROE ISLANDS

Torshavn, Faroe Islands | 8,000 m^2 | 2023–2026

Incorporating mass timber construction and detailed microclimate analyses, our design for the campus extension of the University of the Faroe Islands demonstrates the benefits of 'reading the landscape'.

Home to some of the world's oldest functioning timber buildings, dating as far back as the 11th century, the Faroe Islands' enduring historic structures, traditional craftsmanship and characteristic architecture have been a distinct inspiration for the design of the university extension. The buildings will be constructed using mass timber (glulam and CLT), and covered with a turfed roof to seamlessly blend the buildings with the iconic landscape of Torshavn.

The new campus features an interior square that serves as the heart. A central 'street' and a large stair are designed to foster everyday interactions, as well as a library, informal study spaces, a canteen, a café, space for research and administration staff, classrooms, and a large flexible auditorium.

Renders by Plomp


Renders by Plomp

Hybrids

Could change be a series of compromises?

The construction industry's outsized environmental impact can no longer be ignored. Standards must change, and business as usual needs correcting.

That said, our industry – an industry that is heavily influenced by slow-moving social, political, and economic systems – is rather difficult to alter. The reality is, that with an abundance of stakeholders and decision-makers holding different interests and agendas, progress and innovation are often compromised in favor of more conventional, low-risk, and cost-efficient methods, despite their impact on our planet.

As a result, progress often takes form in paths of compromise, opening new opportunities that work together with long-standing frameworks.

Hybrid-timber construction, combining wood with other materials such as steel and concrete, offers solutions that steadily propel our industry toward more responsible design choices.

Render by Vivid-Vision

NEOMA

Reims, France | 26,000 m² | 2022–2025

Located west of the center of Reims, NEOMA's new campus will be set in Port Colbert, a once industrial neighborhood, that is now in transition. Partially abandoned since its days of industry, when it was home to breweries, cast-iron and aluminum workshops, the area has recently been tagged for revival. The objective of both the city of Reims and NEOMA is to breathe new life into the area while preserving and enhancing what defines its identity and sense of place: its history and industrial heritage.

In recent years, the area has seen budding small businesses and local pop-up events that have repopulated the site. The new campus design is inspired by this entrepreneurial atmosphere that has changed perceptions of the area from a mere location to a meaningful place in people's minds. The design aims to keep this sense of opportunity and openness, creating an invitation for people to influence and take ownership of their environment.

Totaling 26,000 m² NEOMA campus Reims will house 85 classrooms, three amphitheaters, and an event space with a 750-seat auditorium. Incorporating an array of timber elements including its wood-frame façade, wood cladding, and wooden structural elements, the design aims to reduce the emissions associated with construction, use, and maintenance of the building.

Render by Sora

URBAN LAB, NTNU

Oslo, Norway | 2,400 m² | 2010–2021

The new communal building on Campus Ås is a link between the preexisting university buildings and recent additions at the Norwegian University of Life Sciences in Ås, Norway. A multifunctional building that includes a canteen, library, auditorium, and study spaces, Urban Lab is a campus center that accommodates all students, workers, and visitors on Campus Ås. The building sits on a new park that joins all three areas of campus, creating new connections and spaces to congregate.

Urban Lab is a timber building that includes a glulam structure with burned and naturally greyed wood exteriors. From inside, the open staircase extends out into the tree-lined slope that the structure sits in. Seen through the transparent facade, the interaction between outdoors and indoors, nature and culture, becomes an integral part of the building. Using a variety of timber materials, the project showcases the strongest attributes of wood: the integrity of the structure, the resilience of the forest, and the warmth of the interior.

Photos by Einar Aslaksen

Render by Sora

MARMORMOLEN

Copenhagen, Denmark | 28,000 m² | 2019–2025

Henning Larsen and Ramboll double down on sustainable leadership with this large timber building in Copenhagen. Challenging architectural conventions as what, once completed, will be one of the largest contemporary timber structures in Denmark, our design for Marmormolen in Nordhavn reimagines the office typology while adapting to the future and opening up to the public.

Pushing structural boundaries, our ambitious design for Marmormolen's 28,000 m², demonstrates how timber in construction can help us rethink some familiar and longstanding status quos. This while combining office, retail, and a generous public program on the waterfront of Copenhagen's Nordhavn district.

Designed to integrate seamlessly with its surrounding context, Marmormolen features metal-clad façades that reflect the scale of Nordhavn's history as an industrial port. Despite being one big volume, the building is divided into smaller cubes that can accommodate the needs of a diverse range of tenants, connecting it to the human-scale and individual experience. Each cube has its own rooftop, complete with terrasses and gardens, and every green space features self-sustaining vegetable gardens as well as butterfly hotels and beehives to promote biodiversity.

Photos by Rasmus Hjortshøj

Render by Sora

WOLFSBURG CONNECT

Wolfsburg, Germany | 257,830 m^2 | 2020–2027

Wolfsburg Connect (WOC) is a new urban district with a dense fabric of sustainable mobility options, green public spaces, and livable streets replacing an underutilized and disconnected site on the Mittellandkanal. Henning Larsen's masterplan for WOC will combine commercial, residential, retail and leisure, along with a new transportation hub, to create a bustling neighborhood on both a horizontal and vertical axis.

Improved connections across the canal to innovation hubs with collaborative workspaces will make the 70,000 commuter workforce a valuable asset to the city. The overlooked Mittellandkanal, previously cut-off from pedestrians by a busy thoroughfare, will become a bustling waterfront district complete with a promenade, canal park, and pedestrian bridge. As the amenity-rich WOC draws commuters and visitors to the area and encourage them to enjoy their city streets, the project will have a significant impact beyond the site's border.

The whole area is to be built in wood and is a major contribution towards the sustainable goals shared by Henning Larsen and the client. The glulam frames create a generous grid throughout the buildings that allow for flexibility and future modulation for tenants. The composite structure combines the best properties from both wood and concrete and gives the decks the strength, sound insulation and thermal massing desired, while still considerably reducing the CO_2 impact of the buildings compared to conventional structures.

Renders by Aesthetica Studio

SMYRIL LINE HQ

Torshavn, Faroe Islands | 2,400 m² | 2021–2026

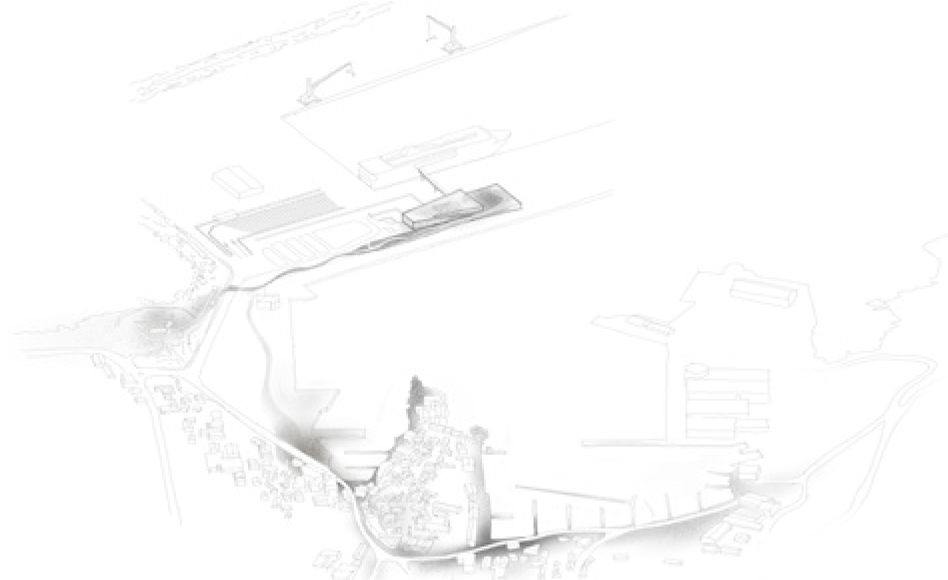
Our design for Smyril Line's new headquarters and ferry terminal in Torshavn, Faroe Islands, pays homage to the traditional structure of Faroese fishing boats, while blending seamlessly into the surrounding landscape and connecting with the heritage of the historic Eastern harbor.

Located in central Torshavn, just around the corner from the Faroese parliament building, the design blends wood and concrete elements with the surrounding landscape.

Paying tribute to local culture and traditions, the wooden structure mirrors the contours of traditional Faroese fishing boats. Crafted with a single axe and tracing their origins back to Viking times, these boats are included in the UNESCO list of Intangible Cultural Heritage of Humanity. The base structure of the building reflects the hand-built coastal paths frequently found on smaller Faroese islands, providing easy boat access from the water through the steep cliff faces to small wooden boat buildings.

Smyril Line's 8,000 m² headquarters will serve three distinct functions, acting as a ferry terminal, an office building, and a logistics center. With a publicly accessible outdoor ramp area, the project will reconnect residents and visitors with the Eastern Harbor.

Renders by Element



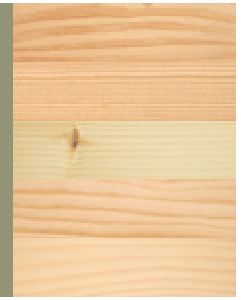
Specifications

European wood species

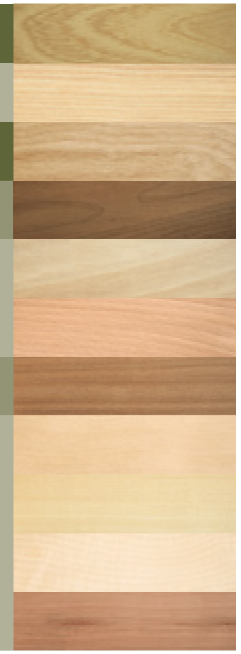
In the following section, the most common types of wood in Europe are described with some of their properties, such as density, durability, and use. As wood is an organic material, the properties can vary significantly from tree to tree.

Density	Qualitative rating of the weight of the species per volume
Strength	Qualitative rating from Young's modulus
Workability	Qualitative rating assessing the ease of processing the species
Durability	Qualitative rating assessing the natural resistance of untreated wood against weather and pests
Typical look	There is a natural variation in the colour and texture of wood

Softwood species	Scientific Name	Density	Dimensional Stability	Strength	Hardness (flooring)	Workability	Durability	Typical look
Douglas Fir	Pseudotsuga menziesii	Light	Good	Strong	Soft	Good	Moderately resistant	
European Larch	Larix decidua	Moderate	Good	Strong	Moderate	Good	Moderately resistant	
European Spruce	Picea abies	Light	Good	Moderate	Soft	Good	Slightly resistant	
Scots Pine	Pinus sylvestris	Light	Good	Strong	Soft	Good	Slightly resistant	
Silver Fir	Abies alba	Light	Good	Moderate	Soft	Very good	Slightly resistant	



Hardwood species	Scientific Name	Density	Dimensional Stability	Strength	Hardness (flooring)	Workability	Durability	Typical look
Black Locust	Robinia pseudoacacia	Very heavy	Moderate	Strong	Hard	Moderate	Resistant	
Common Ash	Fraxinus excelsior	Heavy	Moderate	Very strong	Hard	Moderate	Not resistant	
Common Oak	Quercus robur	Heavy	Moderate	Strong	Moderate	Good	Resistant	
Common Walnut	Juglans regia	Moderate	Moderate	Strong	Moderate	Very good	Moderately resistant	
European Aspen	Populus tremula	Light	Moderate	Weak	Soft	Moderate	Not resistant	
European Beech	Fagus sylvatica	Heavy	Poor	Very strong	Hard	Good	Not resistant	
Scots Elm	Ulmus glabra	Heavy	Poor	Moderate	Moderate	Moderate	Slightly resistant	
Silver Birch	Betula pendula	Heavy	Moderate	Strong	Moderate	Good	Not resistant	
Small-leafed Linden	Tilia cordata	Light	Good	Weak	Soft	Very good	Not resistant	
Sycamore Maple	Acer pseudoplatanus	Moderate	Moderate	Weak	Moderate	Good	Not resistant	
Wild Cherry	Prunus avium	Moderate	Good	Moderate	Moderate	Good	Not resistant	



Source: Træinformation, træ 69 (træarter)
Kucera, et. al.: Einheimische und fremdländische Nutzhölzer (1994)
www.wood-database.com

Softwoods

Density (weight)	Light
Dimensional stability	Good
Strength	Strong
Hardness	Soft
Durability	Moderately resistant
Workability	Good
Typical use	Structural Plywood Flooring Windows Paper

Douglas Fir
Pseudotsuga menziesii

Douglas Fir is a softwood originating from North America but is now also common in Europe. It is a versatile structural wood for outdoor use, commonly used in North America.

Density (weight)	Moderate
Dimensional stability	Good
Strength	Strong
Hardness	Moderate
Durability	Moderately resistant
Workability	Good
Typical use	Structural Windows Doors Boats

European Larch
Larix decidua

European Larch is a softwood, often containing resin. Although larches are conifers, they lose their needles in autumn. Larch is one of the toughest European softwoods and is often used for weathered structures.

Density (weight)	Light
Dimensional stability	Good
Strength	Moderate
Hardness	Soft
Durability	Slightly resistant
Workability	Good
Typical use	Structural Interior Musical instruments Particleboards Fiberboards

European Spruce
Picea abies

Spruce is one of the most important European species and dominates the forests of Northern and Central Europe. Spruce is a light but still strong softwood species, which makes it very popular for construction and products such as glulam and CLT.

Density (weight)	Light
Dimensional stability	Good
Strength	Strong
Hardness	Soft
Durability	Slightly resistant
Workability	Good
Typical use	Structural Interior Furniture Windows Doors

Scots Pine
Pinus sylvestris

Scots Pine is a softwood and widespread on the Northern Hemisphere. Pine contains resin and is therefore relatively resistant against weather and pests. Together with spruce, pine is widely used as a structural material and for pro-ducts such as CLT and plywood.

Density (weight)	Light
Dimensional stability	Good
Strength	Moderate
Hardness	Soft
Durability	Slightly resistant
Workability	Very good
Typical use	Structural Interior Composite boards Particleboards Fiberboards

Silver Fir
Abies alba

Silver Fir is a softwood and has similar properties to spruce but unlike spruce it contains no resin and is mostly used in interiors. Together with spruce and pine, this is the third important structural wood for all widely used timber products.

Hardwoods

Black Locust
Robinia pseudoacacia

Black Locust is a very heavy hardwood originating from North America. It is one of the heaviest and most resistant species grown in Europe. As black locust is not widespread, it is only used for special construction, where very hard or resistant wood is needed.

Density (weight)	Very heavy
Dimensional stability	Moderate
Strength	Strong
Hardness	Hard
Durability	Resistant
Workability	Moderate
Typical use	Structural Interior Fences Water constructions Boats

Common Ash
Fraxinus excelsior

Common Ash is an elastic hardwood used for many indoor purposes such as flooring or furniture.
This wood is very strong and hard but not resistant to weather. For engineered structures, there is a rising demand of ash-glulam, which has an increased strength compared to traditional softwood glulam.

Density (weight)	Heavy
Dimensional stability	Moderate
Strength	Very strong
Hardness	Hard
Durability	Not resistant
Workability	Moderate
Typical use	Structural Veneer Flooring Furniture Tool handles Sports equipment

Density (weight)	Heavy
Dimensional stability	Moderate
Strength	Strong
Hardness	Moderate
Durability	Resistant
Workability	Good
Typical use	Structural Interior Furniture Windows Cladding

Common Oak
Quercus robur

Common Oak is a widespread species with around 200 different types around the globe. It is a versatile wood used for all types of structures and is very resistant, which is why it is common for outdoor use. Oak is also popular for interior fittings, flooring, and furniture.

Density (weight)	Moderate
Dimensional stability	Moderate
Strength	Strong
Hardness	Moderate
Durability	Moderately resistant
Workability	Very good
Typical use	Interior Furniture Veneer

Common Walnut
Juglans regia

Common Walnut is an exclusive hardwood with a big variability in texture. Rootstocks of walnut trees are often dug out as the texture of the rootwood is much sought-after. Walnut is mostly used for furniture and decorative veneers.

Density (weight)	Light
Dimensional stability	Moderate
Strength	Weak
Hardness	Soft
Durability	Not resistant
Workability	Moderate
Typical use	Plywood Particleboards Fiberboards Packaging

European Aspen
Populus tremula

European Aspen is a very light and fast growing hardwood that is mostly used as a cheaper supporting material, e.g. in the fiber and particleboard industries or for plywood. Aspen is also used for packaging and paper.

Density (weight)	Heavy
Dimensional stability	Poor
Strength	Very strong
Hardness	Hard
Durability	Not resistant
Workability	Good
Typical use	Structural Plywood Interior Furniture

European Beech
Fagus sylvatica

European Beech is the most common hardwood used for applications such as structures, construction products, and flooring. This wood is very suitable for steam bending and therefore widely used in the veneer and furniture industry. New products such as BauBuche, a laminated beechwood veneer, increases the use of beech as a structural material.

Density (weight)	Heavy
Dimensional stability	Poor
Strength	Moderate
Hardness	Moderate
Durability	Slightly resistant
Workability	Moderate
Typical use	Exclusive interior Furniture Flooring Veneer

Scots Elm
Ulmus glabra

Scots Elm is an exclusive hardwood, mostly used for interior fittings and furniture. Dutch elm disease (DED) has destroyed a large part of the elm tree population since the early 20th century and is responsible for the complete extinction of some less resistant elm species.

Density (weight)	Heavy
Dimensional stability	Moderate
Strength	Strong
Hardness	Moderate
Durability	Not resistant
Workability	Good
Typical use	Plywood Interior Furniture Instruments Firewood

Silver Birch
Betula pendula

Silver Birch is a hardwood widespread in the Northern Hemisphere. This wood tends to discolor when in contact with metals. Birch is used indoors and common for interior fittings, furniture, and plywood and is not used as a structural wood.

Density (weight)	Light
Dimensional stability	Moderate
Strength	Weak
Hardness	Soft
Durability	Not resistant
Workability	Good
Typical use	Plywood Fiberboards Packaging Pulpwood

Small-leafed Linden
Tilia cordata

Small-leafed Linden is a hardwood species. This wood is not used outdoors or as a structural wood but its highly malleable nature makes it popular for wood carving. For that reason it is commonly used for timber products such as fiberboards or plywood.

Density (weight)	Moderate
Dimensional stability	Moderate
Strength	Weak
Hardness	Moderate
Durability	Not resistant
Workability	Good
Typical use	Interior Veneer Furniture Kitchen utensils

Sycamore Maple
Acer pseudoplatanus

Sycamore Maple is a hardwood of light color that can be found with quilted or curly decorative grain patterns. This wood is not used not as a structural material but instead used for indoor use such as interior fittings, parquet flooring, furniture, and decorative veneers.

Wild Cherry
Prunus avium

Wild Cherry is an exclusive hardwood used for premium interior fittings, furniture, flooring, and decorative veneer. It is not used as a structural wood. Wild cherry is not widespread and often only available in small dimensions.

Density (weight)	Moderate
Dimensional stability	Good
Strength	Moderate
Hardness	Moderate
Durability	Not resistant
Workability	Good
Typical use	Premium interior fittings Furniture Flooring Veneer


Photo by Kasper Kyndesen

Wood treatment

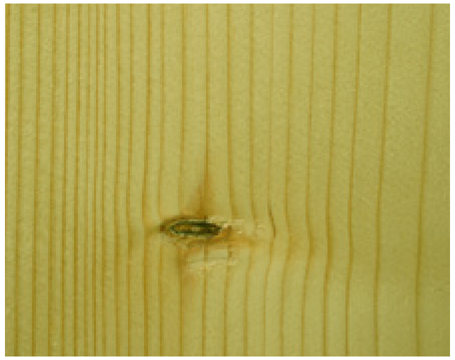
Ways to change the properties of wood.

Many untreated wood species can withstand environmental influences and are more or less resistant against weather or pests, such as insects or fungi. Wood preservation should first and foremost happen through choosing a wood species suitable for the application and following the construction rules of protecting wood. One important design principle to remember is not fully exposing the wood, but rather sheltering it through cladding with a generous overhang. Another important design principle would be keeping the wood a sufficient distance above the ground, in order to avoid future damage and potential rot through rain splashback or contact with the soil. There are many different treatment options to extend the natural lifespan of wood or change the appearance. Two possibilities would be wood modification, where the wood properties are altered through chemical or thermal treatment methods, or by adding a surface finish to protect the wood from weather elements and thereby changing the look of the wood.

Wood modification

Wood modification methods change the cell structure of the wood and thus modify the properties of the material. This can extend the lifespan of the wood and make it more dimensionally stable and resistant to pests. The wood will still weather and change in color over time.

In addition to the methods listed here, there are modifications from the natural preageing of wood through weathering or treatment from fungi.



Pressure impregnation

This impregnation is based on chemical salts penetrating the wood under pressure for several hours and is especially suitable for weather-exposed wooden parts. It is an effective and affordable way of protecting wood, however the substances can be classified as suspected of damaging an unborn child (H361) and are acutely toxic in water. Chemical wash-off is an environmental problem. Depending on the degree of impregnation, the protection may only be on the surface, leaving the core still unprotected. NTR certified systems are more effective. The impregnation is service-free. The lifespan of a cladding is expected to be up to 60 years.

Source: Report Skog og landskap 16/2014

Linseed impregnation

A thermal treatment plus natural, non-toxic linseed oil impregnation (such as Saga Wood®) minimizes the moisture absorption in the wood, which increases the durability. Maintenance through a reapplication of linseed oil is recommended at least every 5 years. Saga Wood® is in durability class 1, giving it a lifespan of at least 25 years for fully exposed and maintained wood and up to 50 years for a partly protected cladding.

Source: Saga Wood

Chemical modification

There are different patented modification methods which chemically change the properties of the wood, increasing its durability.

Acetylated wood (Accoya®) is fast-growing radiata pine that is impregnated with harsh acetic anhydride. The final product does not have toxic content. The resistance and dimension stability are improved and the wood keeps its light color for an extended period of time before weathering. The lifespan of Accoya wood is up to 50 years outdoors above ground.

Furfurylated wood (Kebony®) is typically pine wood that is impregnated with harsh furfuryl alcohol to improve the natural resistance and dimensional stability of the wood. The final product does not have toxic content. Furfurylated wood is darker than untreated wood. The lifespan of Kebony wood is guaranteed at 30 years and can be up to 60 years.

Source: Accoya by Keflico & Kebony

Thermally modified timber (TMT)

The thermal modification of wood is chemical free and is generally conducted at temperatures of 160-230 °C under a reduced oxygen content. TMT develops a characteristic smell and turns darker in color. The higher the temperature, the more durable the wood gets but the process deteriorates more of its mechanical strength. Therefore, TMT is usually not used on structural wood. Thermally modified wood is service-free and in durability classes 1 to 3, with lifespans from 15 to 50 years in outdoor applications.

Source: IHD Dresden, Merkblatt TMT.01 and TMT.02

Burnt wood / Charred wood

Charred wood is a natural alternative to chemically treated wood. The top layer of the wood is burnt and the char creates a protective layer, which doubles the wood's resistance. The charring is finalized in the factory and not on the building site. Burnt wood has an expected lifespan of up to 50 years, although the surface can flake off if exposed to mechanical manipulation.

Source: Charredwood, BurntWood

Preparatory coatings

Surface treatments add mainly a protective or aesthetic value to the wood. Protective coatings serve two different intentions: waterproofing to reduce moisture in the wood and chemical treatment to reduce mould growth. They usually need a refreshment every few years to prolong the life of an exterior building component and to maintain the protective function.

Varnish

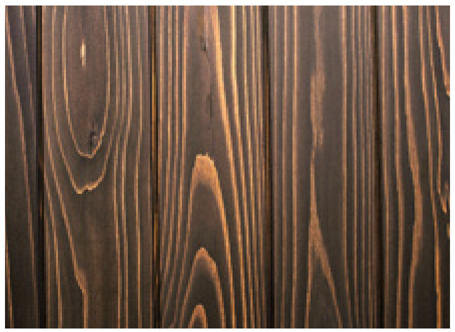
A transparent coating with a silicone, wax, or oil base offers limited protection. The wood usually discolors with aging, due to little to no UV protection. There are different types of clear varnishes such as shellac or polyurethane (robust protection, plastic appearance). For a more natural appearance there is oil varnish, consisting of synthetic alkyd resins in solvent, but this has a high VOC content. Maintenance interval for outdoor applications: approx. every 1-5 years, depending on the system.

Source: Williams, S., Wood Handbook (1999)

Opaque paint

A surface treatment with paint covers and protects the wood. It can have a matte or glossy finish and the wood's natural color does not show through. Maintenance interval for outdoors: approx. 10 - 20 years. In order to minimize the negative environ-mental impact, in particular micro plastic accumulation, keep an eye on the biocide content, the VOC content, and avoid paints with synthetic resign (plastic) binders.

Source: Williams, S., Wood Handbook (1999)
and Environmental Action, Plastic Paints (2022)



Wood stain

Wood stains do not form a film and have a lower content of pigment than in paints, so they are partly translucent. The wood color and texture is still visible. Stains can be water or solvent based. Maintenance interval for outdoor applications: approx. 2 - 10 years, depending on the system and thickness.

Source: Williams, S., Wood Handbook (1999)

Iron sulphate

Also called ferrous sulfate or green vitriol. A treatment with iron sulphate gives the impression of weathered or aged wood. This mimics the discoloration of the natural aging process. The pre-weathering is gradually replaced by natural aging and is maintenance-free.

Source: Swedish Wood (swedishwood.com)

Falured

A natural pigmented surface treatment with a long history, especially in Sweden. It preserves the wood while allowing it to breathe. Falured is based on products from copper mines which are mixed with linseed oil. Maintenance interval for outdoors applications: up to 15 years.

Source: Falu Rödfärg (falurodfarg.com)

Wood tar

A natural treatment with a very characteristic smell, produced by burning tree stumps or charcoal. It has a translucent dark brown color and leaves the surface breathable. The tar is heated up before application and needs some weeks to dry. Maintenance interval for outdoors: approx. 10 years.

Source: Auson (auson.se)

Linseed oil paint

A traditional natural finish, which leaves the wood breathable and is solvent-free. The applied paint needs several days to dry, but is then providing a long-term protection. Maintenance interval for outdoors: approx. 15 years.

Source: Brounds & Co. (linseedpaint.com)

Structural wood

4 common timber materials.

Solid wood

Solid wood is a traditional building material. Logs are sawn into beams and planks, with planed or rough sawn surfaces. Typically softwood species such as spruce and pine are used. Boxed heart timber includes the pith in the center of the tree. This type of beam tends to crack and twist, which is more of an aesthetic issue than a structural problem. Free of heart center timber (FOHC) has the pith removed, which reduces the cracking and twisting.

Wood is a natural material always adjusting to the ambient air humidity. The construction wood should therefore be in equilibrium with the air moisture at the place of installation, as this reduces uneven movement, which can lead to damages. This does not only apply to solid timber, but all construction wood. Traditionally, timber used to be air-dried, but now most of the conventional construction wood is kiln-dried. Typical applications are in standard structures for family homes and constructions at hidden places, where the requirements for visual quality are low.

Glulam

Glued laminated timber, also called glulam, is composed of layers of wood glued together into structural elements as beams and columns. Planks are kiln-dried, planed and glued together with finger joints to lamella. The lamella are then gathered and bonded to engineered wood, which also can be formed into bent shapes.

As opposed to solid wood, glulam has a reduced tendency of twisting and cracking. As major defects in lamella get removed, higher strengths can be achieved than with solid wood. The different quality and strength classes allow for the most suitable glulam to be chosen for each application, also in dimensions of length and height, which are not possible for solid wood. Typical applications are in structures with higher requirements for strength and visual quality, such as big dimensions and curved shapes.

Cross-laminated timber (CLT)

CLT is an engineered wood panel, consisting of layers of timber bonded together. Each layer is oriented perpendicular to adjacent ones, which gives the panel improved structural properties, uniformity in both directions, and reduced warping and shrinking.

The panels are stronger than solid wood, as defects in the wood are removed. Cross-laminated timber is comparable to plywood, but with significantly thicker lamella. The panels are usually built up symmetrically with the top layers in the same direction.CLT is used in mass timber structures and has experienced an increased popularity in the last decade, as it offers a relatively easy way to build in wood. It is a versatile material for different applications as load-bearing walls, ceilings and roofs.

Laminated veneer lumber (LVL)

LVL is an engineered wood panel with thin layers of wood bonded together. As opposed to products like CLT and plywood, the orientation of the veneers is not alternating and symmetrical, but predominantly parallel. This makes the properties of the panel more directional and comparable to the ones of glulam.

The thickness of the veneers of LVL is similar to plywood veneers, which are distinctively thinner than lamellae of glulam or CLT.

Laminated veneer lumber has improved structural properties compared to solid wood or glulam. The removal of wood defects in the veneers and the increased uniformityreduces the warping and cracking of the panels. Typical applications of LVL are heavy-duty beams and columns, but it is also used as panels for floors and walls in mass timber, similar to CLT.

Structural systems

6 common structures of modern timber construction.

There are many different ways of building in wood. Some typologies such as log structures have been used for centuries, others such as prefabricated room modules were just developed recently. Not every system fits every project, so it is important to choose a suitable structural system for the project.

In recent years, advancements in prefabrication and structures for multi-storey houses have increased in importance, as they allow for high precision with a reduced building time. This allows for new types of buildings such as high rises to be constructed in wood.

This section focuses on typologies of commonly used modern timber constructions.

Mass wood

Mass wood construction consists of solid wood panels like CLT as the main structural system. The boards are used as prefabricated parts for walls, ceilings and roofs and are supplemented by build-ups to achieve the desired functions and properties.

Mass wood is the ideal typology for buildings with medium to short spans and a large number of repetitions. It is suitable for multi-storey buildings, ideally up to six storeys, such as student housing or hotels. Mass wood is very versatile, so it can be applied in many other situations as well and is well suited for buildings with a combination of different typologies. There are alternative forms of mass wood not using cross-laminated timber, like products such as stack elements or doweled solid wood panels.

A variety of products focus on omitting adhesives through friction connections with dowels, bolts, screws or nails. Those systems are not as common in CLT and are rather used in smaller private or niche projects with up to three storeys. They are not suitable for longer spans or big-scale projects due to the limited production capacity and the increased load volume for transportation.

There are alternative products to CLT that are bonded with a glue-free, dowel connection. They can create a build-up consisting of wood in a thickness so big that an insulation layer can be omitted. Examples of products in this category are WLT® by Aalto Haitek, NUR-HOLZ® and Wood100® by Thoma Holz.

Timber frame elements

Timber frame elements are prefabricated parts for walls, ceilings, and roofs. They consist of structural frames with insulation filled cavities and are covered on both sides with panels and surface finishes.

The degree of prefabrication varies from very basic, only including the frame and a panel on one side, up to complete walls with finish and installed windows.

The prefabrication guarantees a production process of high precision and quality that is not affected by weather influences. The elements allow a fast installation process, where the building is weather-tight directly after the installation.

Timber frame elements are applied in a large variety of building types and are also well suited for multi-storey construction. They provide slim walls as the insulation is already integrated into the frames and are ideally suited for ceilings with spans up to 6 meters.

Facade elements

Facade elements are both used in new construction and refurbishment, to add or change and improve the building envelope. They are built up like timber frame elements, but do often not need a structural frame so long as they are not load-bearing. The aims are among others to improve the thermal insulation, add a new weather-tight cladding, and change the aesthetic expression.

The elements are prefabricated and suit all types of buildings. The refurbishment with facade elements is a good alternative to tearing down and constructing a new building.

Room modules

Room modules are similar to prefabricated wall and floor elements but with the difference of producing a three-dimensional space. The enclosing walls and ceilings can be build-ups of different typologies as mass wood or timber frame elements.

Compared to two-dimensional elements, the room modules are usually manufactured with a higher degree of prefabrication, often including the complete finish inside and outside. The room modules are then transported to the site and installed in a very short time through simply connecting them to each other.

Room modules are ideal for temporary structures such as schools or shops, or as an efficient way of building offices, hotels, or apartments; ideally projects with a big number of repetitions. The realization of bigger rooms, such as classrooms is possible, as well as multi-storey structures and creative architecture.

Composite timber-concrete

Wood-based hybrid floors are a merge of wood and concrete, with a strong bond between the two layers. Each material is used to its own advantage, such as the high tensile strength of wood and the compression strength of concrete. The bond is obtained through shear connections in the wood or steel.

The structural wood can be a mass wood layer such as CLT, timber beams, or as a frame construction. The floors can be completely prefabricated or the concrete layer can be casted on site, depending on the chosen system. The advantage of wood-based hybrid floors is an increase in the possible span and improved sound insulation and fire safety. It is often used in multi-storey projects, where longer spans and higher requirements apply.

Box elements

There are a number of different types of ceilings and roofs based on rib- and box-shaped elements. They combine many functions of a ceiling into one element, from structural capacities to thermal insulation, from acoustics to fire resistance. This makes them comparatively slim and lightweight while being able to span long without support.

Ideal applications of rib- and box-shaped elements are in places with long spans and where the available room height is little. This can be applications such as roofs of halls, ceilings in refurbishment, and the addition of extra floors in existing buildings. Depending on the system, ceilings and roofs of this typology can obtain long spans, such as with Lignatur® with over 10 meters and Kielsteg® with more than 25 meters.

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