Sustainable, High-Performance Building Solutions in Wood (HiBiWood)

2020-1-LV01-KA203-077513

TIMBER-SPECIFIC TOPICS (FACT SHEETS)

Learning materials prepared by FH Campus Wien, Austria

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DECLARATION

The HiBiWood project addresses the anticipated requirements for sustainable and high-performance building construction in timber within higher education by establishing a comprehensive and interdisciplinary BSc/BA curriculum that incorporates innovative student-centered learning methodologies, including project-based learning, learning by doing, and integrated planning.

The timber-specific topics (fact sheets) in this report were generated by participating students during the project and subsequently refined and augmented by the project partners. These resources presently serve as internal teaching aids within the scope of the project and are not intended for dissemination or publication to a wider audience.

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Vertical load transfer - spans and systems for timber construction

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Structural grid

First of all, to determine efficient grid spacing, it is important to understand possible span ranges for mass timber floor panels. Due to their relative light weight, allowable spans for these panels are often governed by vibration and deflection rather than bending or shear capacity. In addition to panel vibration design, vibration performance of the framing system as a whole, including beams, should be taken into account. The table below illustrates example ranges based on panel size, assuming stiff supports. (Each project's specific span, loading and support conditions, as well as manufacturer-specific design properties, should be accounted for when selecting panel thickness.)

Panel	Example Floor Span Ranges
3-ply CLT (4-1/8" thick)	Up to 12 ft
5-ply CLT (6-7/8" thick)	14 to 17 ft
7-ply CLT (9-5/8")	17 to 21 ft
2x4 NLT	Up to 12 ft
2x6 NLT	10 to 17 ft
2x8 NLT	14 to 21 ft
5" MPP	10 to 15 ft

Table 1: Example mass timber floor panel span options

Simplistically, there are two main grid options for mass timber buildings: square and rectangular. In deciding which to use, there are a number of factors to consider.

Based on completed buildings in the US, **square grids** tend to be in the range of **20×20 ft (6x6 m) to 30×30 ft (9x9 m)**. Although a mass timber panel may be able to span the 20-ft (6 m) distance between support beams in a 20×20-ft (6x6 m) grid, an alternate method would be to include one intermediate beam within each bay to reduce the span of the mass timber floor panel. For example, a 20×20-ft (6x6 m) grid could have one intermediate beam so 3-ply CLT floor panels spanning 10 ft (3 m) can be used. Larger square grids such as 28×28 (8.5x8.5 m) or 30×30 ft (9x9 m) with one intermediate beam can also be used. This typically results in the use of 5-ply CLT or 2×6 NLT floor panels, spanning 14 or 15 ft (4.3 or 4.6 m). In general, thinner floor and roof panels may result in lower material costs. However, lower horizontal panel costs may be offset by higher beam (and perhaps column) costs, and additional intermediate beams also need to be coordinated with MEP systems. As such, a cost analysis for thicker floors and fewer beams vs. thinner floors and more beams may be necessary.

Rectangular grids are usually in the **12×20-ft (3.6x6 m) to 20×32-ft (6x9.75 m)** range. The main difference with a rectangular grid is that intermediate beams tend not to be used, often simplifying the approach to accommodating MEP. The narrower grid dimension is typically based on the span capability of the floor. The larger grid dimension is based primarily on programmatic layout, while taking into account economical spans for glulam. Projects can use a 12×32-ft (3.6x9.75 m) grid with 5-1/2-in (12.7 cm) CLT panels spanning 12 ft (3.6 m), and in another stucture can be used a 20×25-ft (6x7.6 m) grid with 2×8-ft (0.6x2.4 m) DLT panels spanning 20 ft (6 m).[1]

Another report also shows typical grid sizes used for Post-Beam-Panel mass timber building systems (Figure 1). Due to the nature of pressing CrossLam® CLT, the maximum length of panel that can be pressed is 40' (12.19 m), and the maximum width that can be pressed is 7'-10.5" and 9'-10.5". The use of augmented grids can create impressive structural efficiencies. An example would be a **30' (9 m)** primary beam span in the Y direction and **15' (4.5 m)** bay spacing in the X direction. Located on exterior bays of the building, this produces large functional spaces.[2]

[1] Ricky McLain, Greg Kingsley (2020) Efficient structural designs for mass timber buildings: the engineer's role in optimization, World Conference on Timber Engineering, Santiago, Chile

[2] Structurlam Mass Timber Corporation (2021) Stucturlam Mass Timber Technical Guide, USA, p. 33

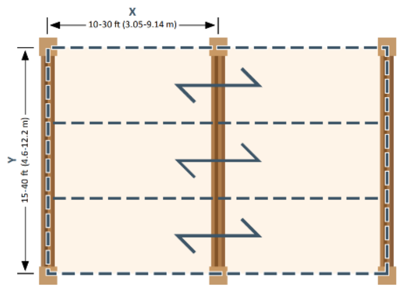

Figure 1: Typical post-beam-panel system grids

Additional variation on the traditional post, column and plate structural grid is that of double-stacked CLT panels, running in perpendicular directions relative to each other. The Rocky Mountain Institute's Innovation Center in Basalt, CO, used this approach. For this project, the structural framework consists of a 20x20-ft grid with 9- ply CLT panels, which are 4 ft (1.2 m) wide and centered over the columns, spanning 20 ft (6 m). On top of and running perpendicular to the 9-ply panels are 3-ply CLT panels. The gaps left between the 9-ply panels were used to run MEP services, which were then covered with an inlaid birch-slatted ceiling system. By utilizing this double CLT system, the design team was able to eliminate beams; they estimate that headroom was increased by over a foot when compared to a system that utilized beams, CLT panels and a raised access floor.

Influence on degree of prefabrication

When selecting grid dimensions, another important consideration is manufacturer capabilities. Most North American CLT manufacturers certified to the PRG-320 Standard for Performance-Rated Cross-Laminated Timber are capable of producing panels between 8 (2.4 m) and 12 ft (3.6 m) wide and between 40 (12.2 m) and 60 ft (18.3 m) long. Minimizing the amount of waste from each panel is key to maximizing efficiency. For example, a grid with 20-ft (6 m) increments could be very efficient; it could use 40-ft-long panels or 60-ft-long panels (if the manufacturer is capable of producing those sizes). On the other hand, a 24-ft (17.3 m) grid may not be as efficient since it would either require 48-ft-long panels (for double spans) or cutting 16 ft (4.9 m) from 40-ft-long panels. Both options increase waste and reduce efficiency. When considering especially long panels, trucking logistics should also be taken into account.

Advantages/disadvantages in different constructions

There are several reasons and advantages of rectangular grid and eliminating the intermediate beam, but the one often cited by design teams is easier MEP coordination. Since exposing the mass timber floor panels on the ceiling side is desired in most mass timber buildings, some creativity in how ductwork, sprinkler lines and other MEP services are accommodated is required. If there are no intermediate beams, the main MEP trunk lines can be run around a central corridor with branch lines extending into each bay. A benefit to this approach is that no intermediate beams means no or minimal penetrations through glulam purlins or girders to coordinate, cut, design for, etc.

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[1] Ricky McLain, Greg Kingsley (2020) Efficient structural designs for mass timber buildings: the engineer's role in optimization, World Conference on Timber Engineering, Santiago, Chile

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Sound insulation vs. load transfer

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Introduction

This document shows the need and possible solutions of sound insulation in timber buildings. It treats general information about sound as well as special features of timber buildings. Especially the node connection of wall and ceiling components was mentioned, as it is a very critical feature of timber buildings.

Basics of sound transmissions

In the field of building physics two types of sounds are treated separately:

- Airborne sound transmission: The sound is generated in the air (e.g. by speaking or music) and stimulates the buildings components to vibrate.

- Impact sound transmission: Sound is generated by direct impacts on component surfaces, especially on floors (walking, jumping, etc.).

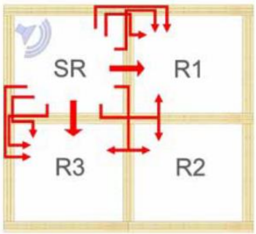

Figure 1: Transmission of airborne sounds via walls [1]

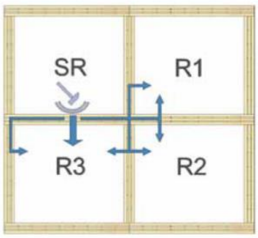

Figure 2: Transmissions of impact sounds in walls [1]

How to avoid sound transmission

While impact sounds of floors are normally solved by building a floating screed, airborne sound and impacts on the walls are more complicated to reduce. In general, there are 3 main measures to do this:

- Increase the components mass: As high mass components tend less to vibrate this is the main tool for classic solid constructions but less for timber constructions which have less weight. For timber constructions the mass of a component can be increased better by adding gypsum fibre board layers, which also can be needed for fire protection, than by using a thicker timber construction or thicker CLT panels (see figure 3)

- Protection barriers: Facing framework like dry lining on walls or suspended ceilings, with sound insulation materials inside, make it harder for sound energy to enter or exit the load transferring component. Frameworks can also be used for installations and contain gypsum fibre boards that are mentioned above.

- Partial decoupling by building sandwich structures: For this you use two load transferring CLT or timber frame elements, separated by a sound insulation material. This is a very efficient way to reduce sound transmission but must be planned very detailed as the two elements must be considered as two different load bearing structures.

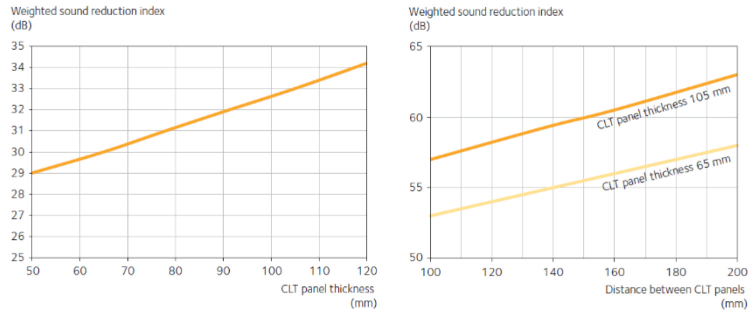

Figure 3: Sound insulation improvement by CLT panel thickness compared to improvement by distance of two CLT panels [2]

Constructional separation of components

the node connection of wall and ceiling components as most critical detail

As shown in figures 1 and 2 sound is not just transmitted directly through walls and ceilings but also over the flanks. In timber buildings sound transmission over the flanks often must be considered, to fulfil the overall sound insulation requirements. Sound transmission over flanks can be reduced by separating components from each other. The need of the separations depends on which of the measured mentioned above have been taken and how efficient they are.

Especially the wall-ceiling connection is a very critical node because it still must transfer all the loads.

Load transferring components can be separated by elastic layers/stripes. The stiffness of the layers must be chosen for every component regarding to the appearing loads. Connectors also must be separated with elastic layers. Good results can also be achieved with steel bearings that are reducing flanking transmission.

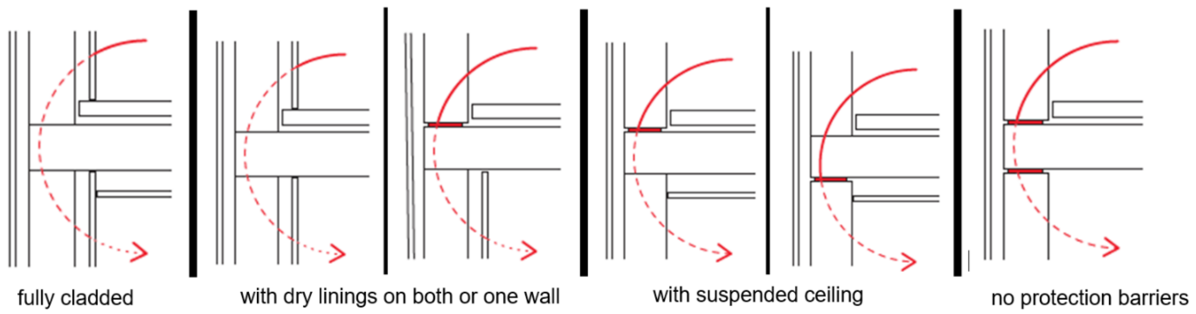

Figure 4: Basic construction rules for the need of elastic separation layers [3]

Figure 5: Elastic layers used for walls and connectors [4]

Figure 6: Example of steal bearing [2]

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Cantilevers – timber

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Overview of structural systems

A cantilever is a structural element which is only connected to one side and extends horizontally. The beam combined with the force pushing down bends the cantilevers and by doing that stress accrues inside the structure. Through that motion the upper part stretches while the lower part wants to compress. The maximum length of the member is determined by three components. First the distance of the compression and tension forces, second by which load the beam is exposed and third what material has been used. From this movement a Moment appears in the joint. Also, it is very important that the whole structure is a stiff construction otherwise a deflection will accrue.

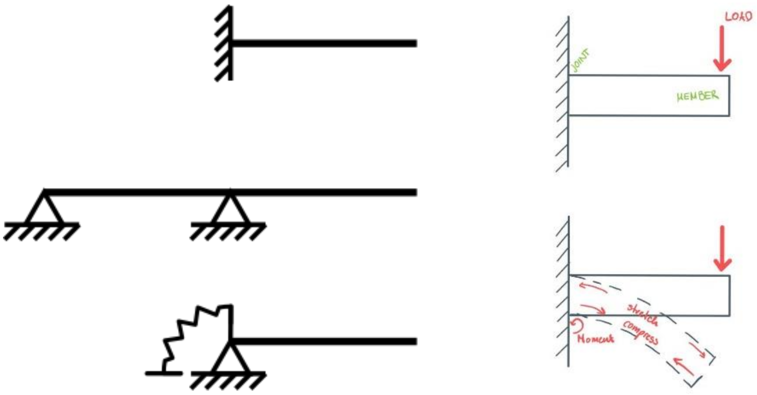

Figure 1. Cantilever beam [5]

The principle of this constructional element shows in three specific types. First the regular one that has already been explained with a full moment connection. The second one is just an extension of a supported beam, and the third type which adds an elastic spring to the end board.

Cantilevers in Architecture are mostly presented by Balcony's or overhanging building parts. Architecture claim that this is a solution for raising the resident density in the building and taking up as little land as possible. Furthermore, though the principal of the cantilevers new design solutions can be developed.

Cross-references with thermal separation

A thermal bridge, also called a cold bridge, is an area of a building construction which has a significantly higher heat transfer than the surrounding materials. This is typically where there is either a break in the insulation, less insulation or the insulation is penetrated by an element with a higher thermal conductivity. Where the building is situated in a cold climate this can result in additional heat loss at these points.

Terminal brides are a big problem that emerge of using a cantilever. For example, in the balcony the joint of the cantilever is the critical part which has an higher thermal conductivity because it is basically an extension of the celling which is leading to the outside. To prevent this loose of terminal energy there are some solutions. First you can use an “Isokorb” which is screwed to the KSH boards. Second you can layer the ceiling panel under with the balcony panel and third you can isolate the area of the joint (Figure 2, 3, 4).

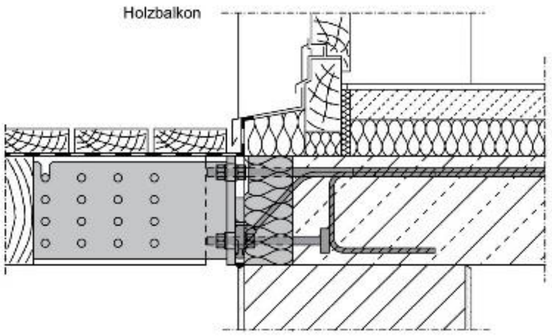

Figure 2. Example: Mitigation of thermal energy dissipation in cantilevered timber structures [6]

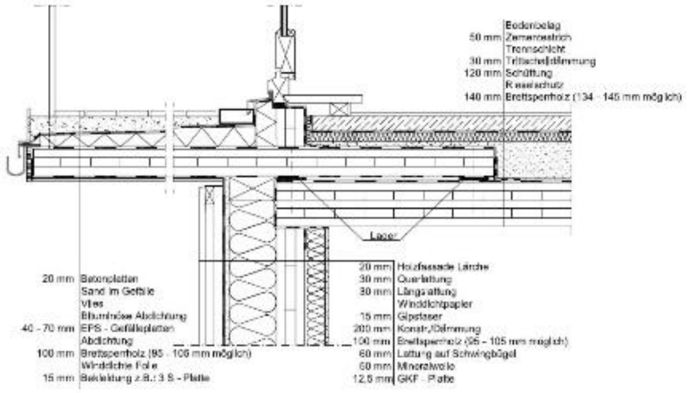

Figure 3. Example: Mitigation of thermal energy dissipation in cantilevered timber structures [6]

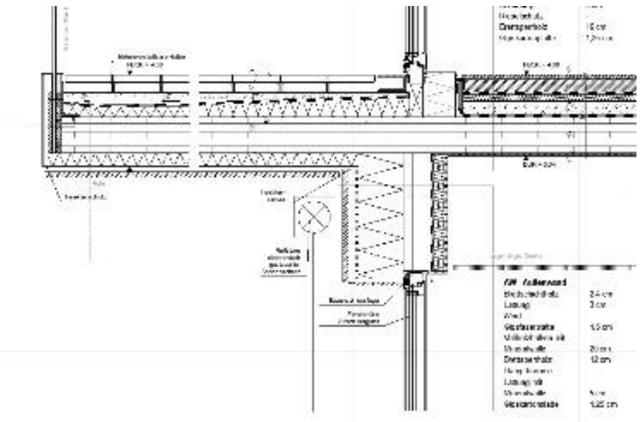

Figure 3. Example: Mitigation of thermal energy dissipation in cantilevered timber structures [6]

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Roof systems

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Introduction

Timber has been the traditional material for building roofs whether in the form of a pitched or a flat roof. The popularity of timber as a roofing material is because it is widely available, is generally light and easy to work with, has an excellent strength-to-weight-ratio and is often a very economic solution. It is also bio-degradable and can be environmentally-friendly when gathered in a sustainable manner. Historically, timber was the most abundant and suitable material from which to build the roof structure. The roof covering was the dominant factor in determining the form of the roof.

Structure

A timber roof has two basic components - the supporting structure and the covering. A timber frame for a flat roof is often the cheapest and the easiest to build when constructing a house. However, since it results in a stunted, blocky-looking appearance, this type of roof is not often chosen as it is less attractive compared to a sloped or pitched roof. In addition, the finishes available for flat roofs are limited and it does not provide a loft or attic space that can be used for storage or water tanks. Unlike pitched roofs, water is not 'shed' off the flat roof and it can also be harder to find and repair leaks.

Roof systems

There are three options for roof systems: pitched (steep) roof, flat pitched roof and flat roof.

Pitched roof

There are two basic methods of construction for timber pitched roofs. These include:
Cut roof: The traditional method of cutting timber onsite and building the roof up using rafters, joists, purlins, ridge boards, and other materials. The exact details will be determined by the size of the roof and timbers required.
This type of roof consists of rafters and joists. The purpose of joists is to prevent the outward spread of the rafters while providing support for the ceiling below. The size of the rafter timbers used will depend on their length from the ridge to the wall plate, the type of roof covering used, and whether or not purlins are used. Keeping the cross-section of the rafters down is a more economical choice, however, larger rafters will be necessary if open roof space is required. Rafters are typically spaced at 400mm, but closer spacing may be necessary to allow small-section rafters and batten, which are fixed to rafters to fix tiles or slates, to be used. Rafter thickness will depend on the size of the gap between them.
Truss roof: This is when the roof is made using factory-made trusses that are delivered to the building site complete before they are erected on the building.
Truss roofs are made up of several factory-made frames or trusses that combine joists, rafters, and struts. A modern truss roof will be designed and manufactured for a certain position in the roof structure. They are made up of timber lengths that are butt-joined and are typically nailed together with plate fastenings rather than a timber joint. Truss timbers can either be bolted together or pegged after being mortised and tenoned.

Flat pitched roof

The flat pitched roof is a mixture of the flat roof and the pitched roof. It is usually a roof with a pitch of between 10 and 20 degrees. As it is a middle way between the two, it brings some of the advantages and disadvantages of the two. For one it gives the possibility to have better waterproofing properties and less intense maintenance. In addition to that, it allows for pleasant optics and a lot of modern building materials for the covering layer.

Flat roof

Timber flat roof construction usually consists of structural joists topped with a decking of plywood or a similar sheet material. Wherever possible, joists should span the shortest distance of the roof plan. The pitch is governed by the roof covering and the required rate of rainwater discharge.
There are a number of different possible methods of creating a fall (slope):
Joists cut to falls with flat soffit: These are simple to fix but may not be very economical in terms of timber usage, unless two joists are cut from one piece.

Joists laid to falls with sloping soffit: Economic and simple but the sloping soffit may need to be hidden by a flat suspended ceiling.
Firrings (tapered strips fixed above the joists) with joist run: Simple and effective but it does not provide a means of natural cross ventilation.
Firrings against joist run: Simple, effective, and provides a means of natural cross ventilation, but uses more timber.
The loadings and span of the flat roof will determine the spacing and sizes of the joists required.
As with concrete flat roofs, a timber construction will be finished with a waterproof covering such as a membrane, or a sheet material such as lead. Insulation will be incorporated within the roof build up, together with a vapor control layer to protect from interstitial condensation.
Garages may be un-insulated, but most roofs above the habitable part of the house will need to be insulated to comply with Building Regulations.

Conservation of energy can be achieved in two ways:
Cold roof: Insulation is placed on the ceiling lining, between the joists.
Warm roof: Insulation is placed below the waterproof covering, above the roof decking.
Inverted roof: Insulation is placed above the waterproof covering.

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Ceiling systems

Types, differences, challenges

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Introduction

While wooden ceilings have always been a frequently used type of construction in single-family houses, in recent years, wooden ceilings are increasingly being used in multi-storey residential buildings. Starting to talk about the specification of wooden ceilings, we can divide them depending on their type and condition.

Possibilities of ceiling systems and their bracing

ceilings with girders (bar-shaped components)

Along with vaults, wooden beam ceilings are the oldest ceiling constructions. The modern forms of this group of ceiling constructions are called timber beam ceilings. They consist of the same functional elements as historical beam ceilings:

- the beam layer together with possible formwork as a supporting structure
- a floor covering that can be walked on, with measures for fire protection and sound insulation
- and an - optional - ceiling cladding.

Possible components for the beam layer: Solid wood (softwood and hardwood timber), beams, fingerjointed solid wood or laminated beams (Double / triple laminated beams and GLT - Glued Laminated Timber)

massive timber construction (flat components)

- CLT - Cross Laminated Timber
- DLT - Dowel Laminated Timber Various joining options
- TCC – Timber Concrete Composite

From an architectural point of view, board stack ceilings represent an interesting alternative to wooden beam ceilings and solid ceilings (concrete or bricks). There are various design forms of DLT or CLT ceilings, sharp-edged, bevelled, with tongue and groove, with cable groove and with an acoustic profile.
mixed forms (timber frame construction)

- Composite beams (Lightweight timber beams / supports)

This form of construction contains ribs and planking. The ribs are mostly made of solid structural timber, which work together with suitable board materials to form planking on one or both sides. Depending on the material chosen, the type of material selected and the type of connection, this beam cladding can either be counted as co-supporting or only stiffening, depending on the material selected and the type of connection.

Figure 1: Common solid wood products and wood-based materials

Differences in single span/multi span beam systems

There is a significant difference between the two framing methods. When you have multiple-span continuous joists, the design moments (bending forces) are reduced and the deflection (sag) of the joists decreases. In other words, with regard to deflection and vibration, continuous joists are stiffer than two simple spans because the two coupled spans act together.

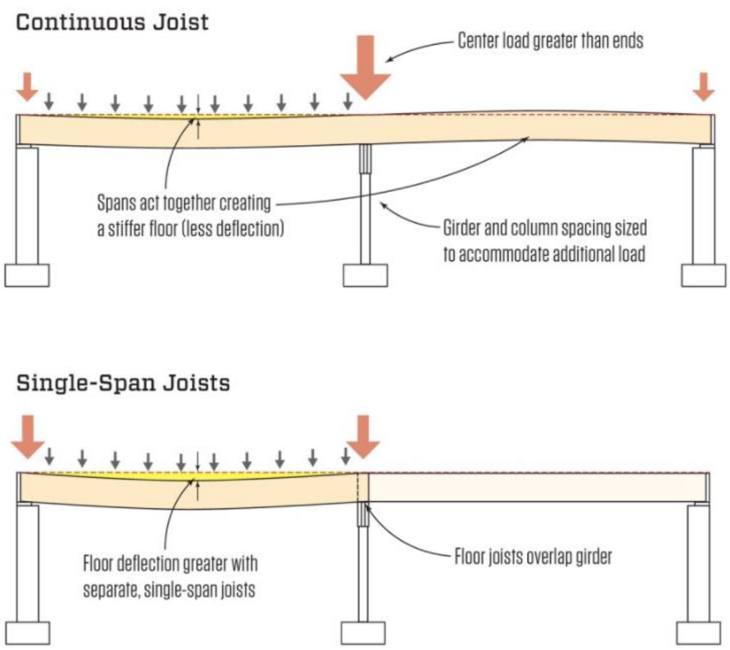

Figure 2: Comparison of single and multi span beams

Consideration of the vibration issue of wood ceilings

The structure of the ceiling, the natural frequency of its components and its stiffness are decisive for the vibration behavior of wooden elements. The natural frequency can be determined by measurement or calculation. In the calculation, the actual static system may be taken into account, e.g. continuous beam effect and also the bending stiffness of the screed.

There are some rules for the construction, that improve this behavior:

- floating screed (laid on a thin layer of insulation) is required in any case.
- wet screeds are more favorable than dry screeds due to their higher mass and stiffness
- a (preferably heavy) fill improves the vibration behavior. (at the same time, it offers the possibility for installations)
- The heavier the fill, the greater the improvement in the subjective evaluation (as "heavy" fill is defined fill with a weight of at least 60 kg/m²)

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Wall systems

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Introduction

Timber is widely used across the world as construction material. With the global pollution increase, timber based constructions are getting more popular as it is more nature friendly than, for example, concrete structures.

Walls are the vertical constructions of a building that enclose, separate and protect its interior spaces. They may be:

- Load bearing structures of homogeneous or composite structures designed to support loads
- Structural frames – framework of columns and beams with nonstructural panels attached to or filling between them.
- Stud walls where studs carry vertical loads, while sheathing or diagonal bracing stiffens the plane of the wall.

Types of timber wall systems

There are several types of timber wall systems used, the most popular are the following:

- Balloon framing
- Platform framing
- Wood post and beam structure
- Cross-laminated timber walls

These wall systems will be explored in more detail for better understanding.

Balloon framing

Balloon framing utilizes studs that rise the full height of the frame from the sill plate to the roof plate, with joists nailed to the studs and supported by sills or by ribbons let into the studs. Balloon framing is rarely used today, but the minimal vertical shrinkage it affords may be desirable for brick veneer and stucco finishes. This was a popular wall system structure in the USA for detached houses. This type of framing should not be used for buildings that has more than two storeys.

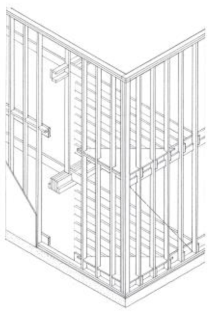

Figure 2: Balloon Frame [1]

Platform framing

Platform framing is a light wood frame having studs only one story high, regardless of the stories built, each story resting on the top plates of the story below or on the sill plates of the foundation wall. Platform framing is also referred to as western framing. This type of wall framing does not have a 2 storey limit and can be built higher than balloon frame structures. This type of structure is better regarding fire safety than a balloon frame.

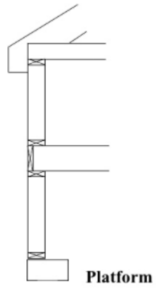

Figure 2: Platform framing [1]

Wood post and beam framing

Post-and-beam construction uses a framework of vertical posts and horizontal beams to carry both floor and roof loads. The beams supporting the floor and roof systems transmit their loads to posts or columns that, in turn, carry the loads down to the foundation system

- Together with plank-and-beam floor and roof systems, the post-and-beam wall system forms a three-dimensional structural grid, which may be expanded vertically or horizontally.
- The skeleton frame of posts and beams is often left exposed to form a visible framework within which nonbearing wall panels, doors, and windows are integrated.
- When the post-and-beam frame is left exposed, as is often the case, careful attention must be paid to the species and grade of wood used, the detailing of joints, especially at beam-to-beam and beam-to-post connections, and the quality of workmanship.

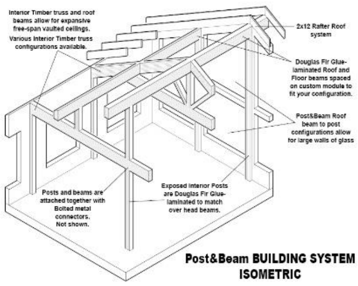

Figure 3: Post-and-beam construction [1]

Cross-laminated timber walls

Cross-laminated timber (CLT) consists of prefabricated, engineered solid wood panels that can serve vertically as structural, load-bearing walls to support CLT floors and roofs.

Because CLT panels are not intended to be exposed to the exterior environment, the design of exterior wall and roof assemblies should aim to keep the panels dry and prevent the accumulation of trapped moisture. Consider the use of overhangs and well-ventilated rain screens to prevent penetration of liquid moisture and integrating air barriers to limit the passage of airborne moisture.

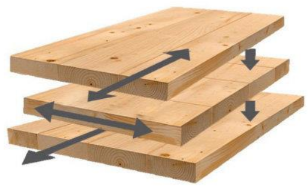

Figure 4: Cross-laminated timber [1]

References

[1] **Francis D. K. Ching** (2019), Wall systems, Hoboken, New Jersey

Airborne sound insulation of partition walls in timber construction

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Introduction

This guideline will show the basics of sound insulation of partition walls in timber construction complemented with some details and figures of basic partition wall structures. It focuses only on airborne sound transmission and will not address impact sound transmission.

Basics of airborne sound reduction

Airborne sound is generally air in motion. By moving a solid body, the air molecules around it start oscillating. As soon as those air waves hit another solid body, it starts resonating and transmits the sound.

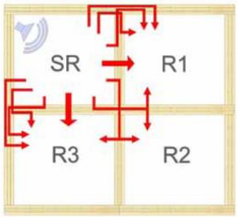


Figure 3: Transmission of airborne sounds via walls [3]

So, in general airborne sound insulation tries to reduce the transmitted sound power from one room to the other. Therefore, the sound reduction level should be as high as possible for maximum acoustic comfort. This reduction can be reached by combining airborne sound insulation and airborne sound absorption.

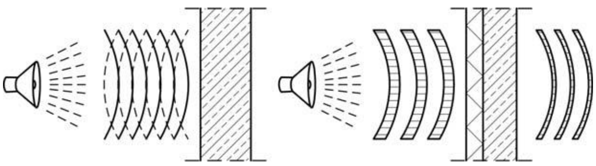


Figure 4: insulation - absorption [1]

Airborne sound insulation is achieved by using heavy and dense building materials. As a result, sound waves are reflected back into the room.

Airborne sound absorption is achieved by using many layers of resonating building materials. These layers reduce the oscillation energy of the air molecules.

There are three important values to differ when it comes to airborne sound insulation:

- *R* = sound reduction index (sound is only transmitted directly through the wall, measured in a test stand)
- *R'* = building sound reduction index (sound is transmitted through the wall and also through neighbouring parts, measured in installed conditions)
- R_W = weighted sound reduction index (calculated by combining the measured sound reduction index *R* with a reference curve and reducing it to one value)

Planning Tipps

- Thoughtful ground plans: Try to avoid complicated details by separating rooms with high acoustic standards from louder rooms. A lot of problems can already be solved during the planning process.
- Air flow equals water flow: Just like you have to make sure that your floors, walls and ceilings are water and vapor proof, you also have to make sure your buildings are airtight. This is an easy and fast way to reduce the airborne sound transmission into a room.
- Avoid voids: All hallow spaces have to be insulated correctly. Make sure the insulation won't settle over the time and create voids in the upper part of walls.
- Increase construction mass: In general walls made of wood are lighter than walls built with solid building materials like concrete or brick. Therefore, try to increase the sound reduction level by combining two heavy layers with one insulating layer. This is also known as the mass/spring/mass concept.

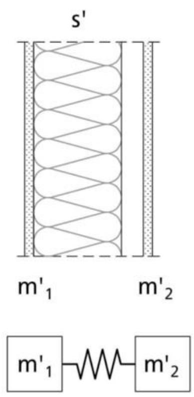


Figure 5: mass/spring/mass system (double layer wall) [2]

Funded by the Erasmus+ Programme of the European Union

Sound insulation of timber frame constructions

With timber frame walls many sheets of panels are the most effective way to reduce the sound transmission. For example, two boards with 1,3cm have a bigger impact than one board with 2,6cm. Furthermore, facing shells are a very good way to increase the sound insulation and be used as installation level. Especially decoupled facing shells have a great impact as well as fully decoupled wall shells.

Sound insulation of solid timber constructions

Decoupling wall shells is the most effective way to increase sound insulation with solid timber constructions. For example, two sheets of 65mm CLT combined with 10cm insulation almost double the weighted sound reduction index, compared to only one sheet of 105mm CLT. Furthermore, adding facing shells and additional panels lead to an increased sound reduction.

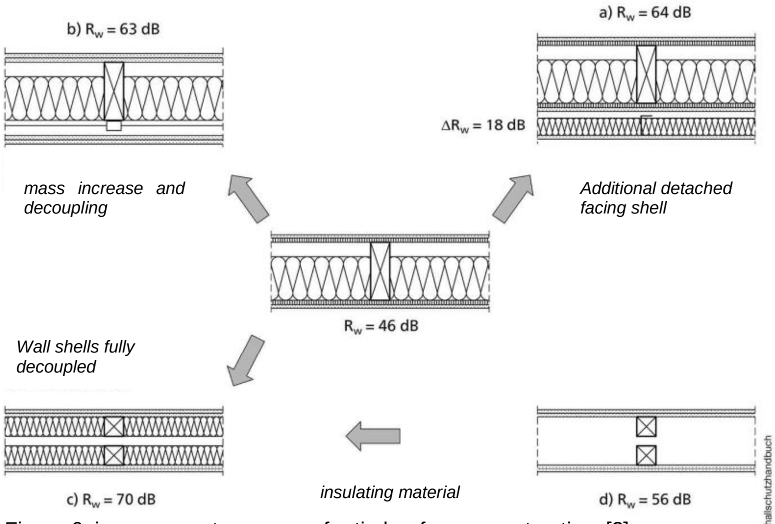
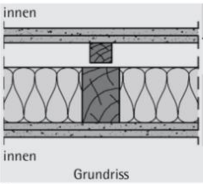
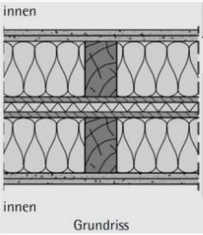


Figure 6: improvement measures for timber frame constructions[2]



Dicke [cm]	Schichtbezeichnung	U-Wert [W/(m²K]	R_w [dB]
1,5 1,5 4,5 1,0 10,0 10,0 1,5 1,5	plasterboard plasterboard structural timber Air gap	0,33	60



Dicke [cm]	Schichtbezeichnung	U-Wert [W/(m²K]	R_w [dB]
1,25 1,25 10,0 10,0 1,6 2,0 1,6 10,0 10,0 1,25 1,25	plasterboard plasterboard structural timber mineral wool chipboard	0,17	65

Figure 6: Sound and termal insulation for timber frame constructions [1]

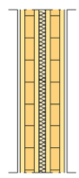
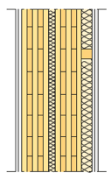
Wall type	Material (mm)	Total thickness (mm)	Fire class	Sound insulation D_w $(C;C_{tr})$
	**Wall type 1** 13 plasterboard 80 CLT panel 30 insulation 80 CLT panel 13 plasterboard	216	REI60	56 (-;-)
	**Wall type 2** 22 × 13 plasterboard 100 CLT panel 30 insulation 100 CLT panel 45 studs and insulation 2 × 13 plasterboard	327	REI90	62 (-;-)

Figure 7: selection of partition wall designs for solid timber constructions [3]

Wall type	Panel thickness (mm)	Air gap between walls (mm)	Insulation thickness (mm)	$R_{w,50-3150}$ (dB)
Single sheet of CLT	65	–	–	31 (-1)
Single sheet of CLT	105	–	–	34 (-1)
Double sheet of CLT	2 × 65	10	2 × 70	55 (-3)
Double sheet of CLT	2 × 65	10	2 × 95	58 (-2)

Table 1: Weighted sound reduction for single and double CLT Wall panels [3]

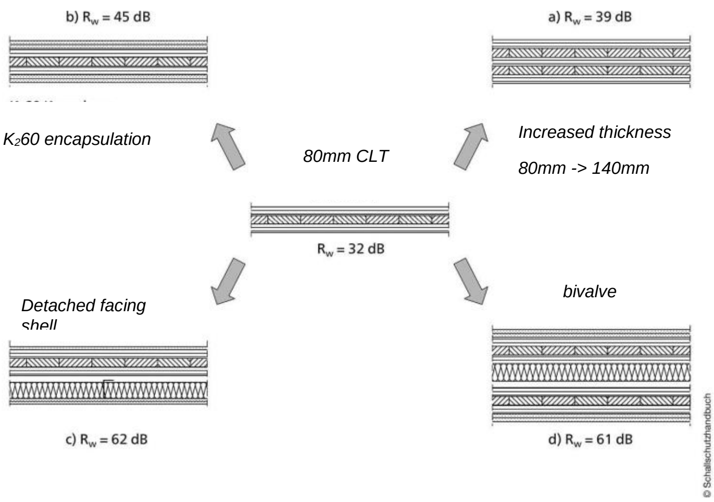


Figure 6: improvement measures for solid timber constructions [2]

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Sustainable, High-Performance Building Solutions in Wood (HiBiW*OOD*)

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Impact sound insulation of partition ceilings in timber construction

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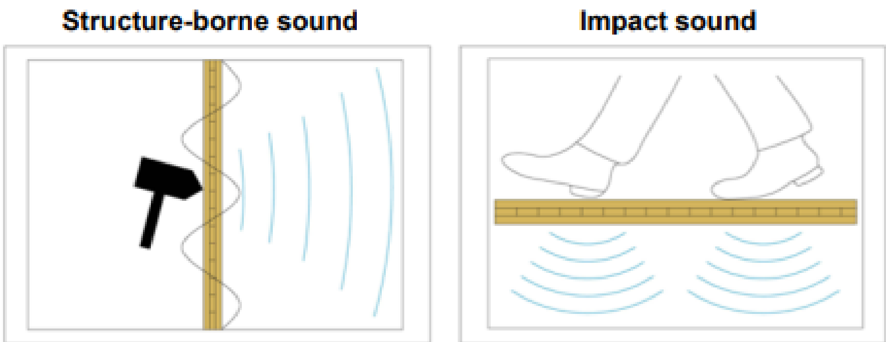
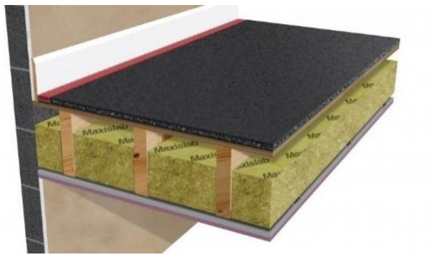
Sound properties in timber

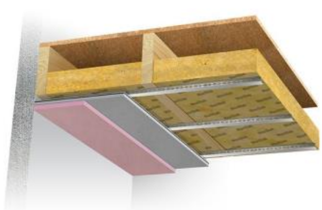
Timber properties in impact sound insulation aren't so good, that's why all partition building parts with timber have something else in them, for example you will need almost 600 mm of timber to achieve the same airborne soundproofing as 180 mm of concrete. Impact sound insulation in floor structures can be improved by increasing the mass or by improving the mechanical isolation of components.
Impact sounds on floors are usually from walking, cleaning and moving furniture. Impact sound insulation is a complex phenomenon, because sound vibrations travel long distances in the frame, which causes air sounds in other spaces.
Timber also has "coincidence" in low frequencies. Coincidence means that the wavelength of the vibrating material coincides with the trace wavelength of the sound wave causing them to vibrate. This means there must be something that improves the floors insulation properties in low frequencies. This can be done with increasing the mass for example adding a creed layer on top.
Standardized impact sound pressure level ($L'_{nT,w}$) between rooms are measured with a device that hits the floor 10 times in one second. Pressure level in Austria cannot exceed 48dB, which is one of the strictest requirements in Europe.



Basic component systematics

- Acoustic mat
- Acoustic mineral wool
- Isolation strips/ Acoustic sealants
- Acoustic membrane





Acoustic/Perforated panels – improving sound insulation.

As well as the slits in the face, panels have cut-outs to the rear or the centre which meet with the slits in the front, creating perforations. These perforations, combined with a cavity behind the panel create resonance, due to the air in the cavity which acts like a spring. In combination with damping provided by mineral fibre in the cavity, sound energy is reduced. This is know as a Helmholtz absorber.

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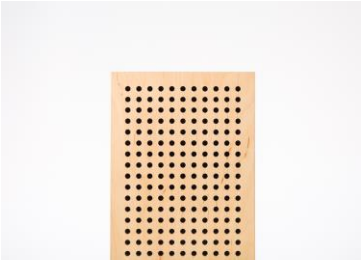
Changing the perforation pattern (in this case by selecting the width between the slits) alters the acoustic performance. Differences in the cavity depth and absorbent material in the void also have consequences.

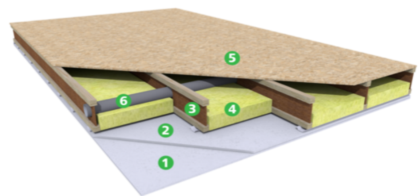

Mixed forms

Hybrid-timber construction systems combine wood with different materials (e.g. steel, concrete and glass) and techniques to deliver a wide range of structural solutions. While it is possible to construct a building entirely of wood, most wood buildings rely on some use of other materials. Sound properties of timber ceilings can be more effective by using mixed forms instead of solid timber.

Examples

Steico timber floors.

Floor construction "Separating"



Floor construction with STEICO I-joists and additional sound protection

1. 15mm plasterboard (Type D).
2. Second layer 15mm plasterboard (Type D), resilient bar @ 400mm centers.
3. Slim **STEICO I-joists** combine load-bearing capacity with efficiency.
4. 15mm OSB stiffens the floor construction and forms a highly resilient subfloor.
5. 100 mm glass wool between joists for sound protection.
6. Services incorporated within the floor zone

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Decoupling – Possibilities in timber construction

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What is decoupling?
Decoupling involves mechanically separating 2 sides of a structure for
the purpose of inhibiting vibration transmission and blocking loud noises from traveling across the wall
You can achieve that by adding a soft layer inthe structure to break the soundwaves path.
Decoupling is arguably one of the most effective methods of soundproofing.

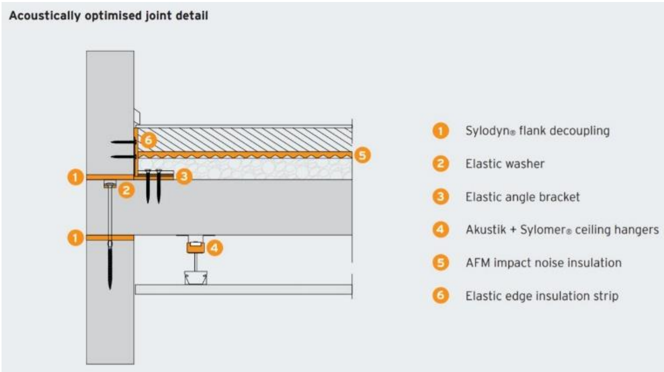

Figure 1: Separation joints

Separation joints and materials
There are several options that can be used for separation two elements in wooden construction. First option are strip bearing – is a closed cellular polyurethane material with outstanding spring characteristics, which make it particularly suitable for the decoupling of vibration and sound. The elastic bearings are available in various degrees of stiffness and colour-coded to enable them to be identified and checked easily on site. Another one is angle brackets. These provide high levels of resistance to shear and tensile forces and verifi ably prevent sound transmission via flanking. The next one are elastic washers. One of the most important fasteners in timber construction is the screw connection. The avoidance of sound bridges in this area requires a clean implementation and the use of elastically decoupled washers.[1]

Figure 2: Types of separation joints

Types of decoupling
Decoupling a wall helps reduce the amount of sound that travels across walls in your building. Most walls are constructed by connecting two pieces of drywall by a single stud. In these cases, any vibratory noise travels through the stud to the other side.
In a decoupled or staggered stud wall, each piece of drywall connects to the wall material with its own stud. The studs do not connect, so the vibratory noise does not have a conduit to travel through the wall. Instead, it travels through its own stud and stops at the interior wall material.

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Constructive moisture protection in timber construction

Overview of critical areas (plinth, façade, wet rooms, connection points, etc.) and critical parameters for structural moisture protection

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What damages timber?

One of the main factors influencing the appearance and service life of wood is moisture. In addition, its effects have not been felt for a long time. When moisture is absorbed into the wood, fungal spores begin to form in it - they are quite slow, so the effects are not noticeable on the wood surface for a long time. Weakened, rotten woodis also used by beetles and other insects, which further damages the appearance and durability of wood structures.

Choice of antiseptic

Antiseptics are divided into four categories according to their composition.

- Inorganic water-soluble antiseptics are suitable for wooden structures that will not be exposed to direct contact with water and moisture. Such antiseptics are used to protect wooden structures and walls indoors. Inorganic antiseptics protect wood not only from moisture and fungus, but also from insects and fire.
- Products based on oils and organic solvents protect the wood both inside and out thanks to a thin protective film formed when the product is applied to the surface. Such protective devices are used for structures that need special protection from moisture, such as saunas.
- The combined compositions not only guarantee the biological protection of the wood, but also ensure the protection of the wood against fire.

When choosing an antiseptic, take into account different nuances - whether it will treat new or older surfaces, whether the wood is indoors or outdoors, or whether it is planned to treat a clean surface or one that has already begun to be damaged by microorganisms.[3]

Shrinkage and Swelling

Wood shrinks or swells when it loses or gains moisture below its fibre saturation point. The amount of dimensional change is estimated at 1% of the width or thickness of lumber for every 5% change in moisture content

Designing according to moisture conditions

Lstiburek proposes that building envelopes and mechanical systems should be designed relative to a set of hazard classes that, taken together, define the environmental load:

- Hygro-Thermal Regions (Severe-Cold, Cold, Mixed-Humid, Hot-Humid, Hot-Dry/Mixed-Dry)
- Rain Exposure Zones (Extreme: >60 in.; High: 40-60 in.; Moderate: 20-40 in.; Low: <20 in.)
- Interior Climate Classes (Uncontrolled, Moderated, Controlled)

To control water penetration, it is necessary to understand the underlying driving forces that may be present. These can include gravity, surface tension, capillary suction, momentum (kinetic energy) and air pressure difference (see Figure 1)

It follows that water penetration can be controlled by eliminating any of the three conditions necessary for penetration.

Building design and detailing strategies can be developed that:

- reduce the number and size of openings in the assembly
- keep water away from any openings
- minimize or eliminate any forces that can move water through openings

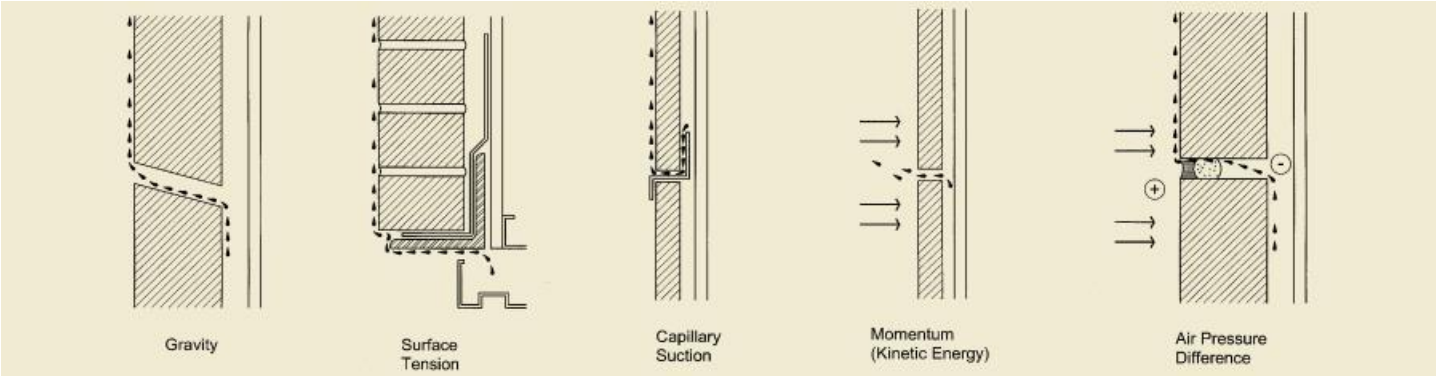

Figure 1: Driving forces that may be present in the construction

The 4Ds

The 4Ds These general water management strategies have been further articulated into a set of design principles
called the 4Ds: deflection, drainage, drying and durable materials.

Deflection

1) placing the building so it is sheltered from prevailing winds, 2) providing sizable roof overhangs and water collection devices at the tops of exterior walls, and 3) providing architectural detailing that sheds rainwater. A pitched roof with sufficiently wide overhangs is the singular design element that can help ensure the long-term durability of wood-frame buildings

Drying

The permeability of cladding, moisture barrier, vapour barrier and interior finish materials will greatly affect the overall drying potential of the wall. Thisis an area currently under study by researchers.

Drainage

The airspace serves as a capillary break to prevent water from excessively wetting the drainage plane

Durable Materials

Durable materials must be selected for use at all locations where moisture tolerance is required. Where deflection, drainage and drying cannot effectively maintain the moisture content of wood components below 28%, the decay resistance of the wood must be enhanced.[1]

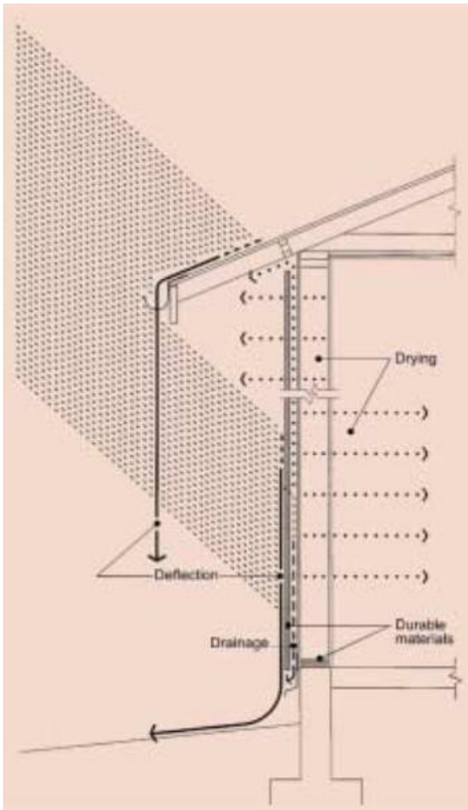

Figure 2: Graphic interpretation of The 4Ds argument

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Prefabrication

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Introduction

This paper highlights the topic of timber prefabrication. Prefabricated systems offer reductions in both cost and time as major advantages when compared to traditional construction methods. They provide environmental benefits. Prefabricated systems start to gain popularity in the industry.

The prefabrication of wood-based composite materials - large structural elements and components

Wood has been used in the construction sector for many years. In recent years, wooden constructions have started to gain popularity again. The revival of wood in the new context is determined by several reasons: the growing importance of sustainability in society - wood is a more environmentally friendly building material, shorter construction time using prefabricated elements, lightness of buildings. Prefabrication is the creation of a building's components offsite, generally in a factory, and then assembling the building onsite. This is a far quicker process than more traditional methods. The technology has been around for a long while, but recent advances have allowed for much more rapid creation of components and even the prefabrication of entire multi-storey buildings. Not only would prefabrication speed up construction considerably, it would also help ensure the quality and consistency of builds. With all components coming standardised and being factory produced, there should be less chance for error and substandard construction methods to negatively impact the end user.

Advantages and disadvantages of prefabrication

Prefabricated systems are flexible and provide the benefit of less construction waste. 80% of production takes place in a factory, where waste materials can be recycled. Modules can be dismantled and used in other projects. General noise and disruption of other buildings is lowered by 30-50% when compared to traditional methods [1].

The prefabricated construction system provides reductions in both cost and time. The phases of site preparation and construction of the modules can be run simultaneously, while in conventional construction, the construction phase happens after the site preparation phase- it helps to reduce up to 40% of construction time.

Process of prefabrication requires more engineers, quality controllers and relatively lower number of skilled workers. Design phase is more costly- it involves intensive prior planning. Safety issues are reduced by about 80%–85%, as most of the work occurs in factories. Because of automation, consistent products are made. Material can be ordered in bulk, and several modules can be fabricated at the same time. This cuts prices and number of transportations [1].

Levels of prefabrication

Prefabricates are made in advance in the factory according to the assembly-line method. The construction of the elements is often the same as traditionally constructed. Pieces of construction timber are planned and chamfered. Appropriate drying process must be applied, helping with change of color of the elements, destroying impurities. Elements are finished with the surface layer and formed as far as possible with complete insulation, in order to reduce assembly time [2]. Problems with building moisture and weather influences are also reduced. Prefabrication technologies can be distinguished by type. Open prefabrication consists usually of the wooden frame construction covered by a wooden based plate. In this kind basic elements like roofs and walls can be made. Closed prefabrication is more advanced, its level can differ. Typically, insulated walls are finished in the factory. Roof trusses are also prefabricated, assembled on the site. In the most advanced systems, whole parts are delivered directly on site, e.g., walls finished on both sides with doors, windows and roller blinds. Module prefabrication is the most advanced. Whole spatial elements of a building are prepared, often whole small buildings [3].

The transportation issues

Transportation costs may be higher. Assembled parts are more difficult to pack. Large prefabricated structures require heavy-duty cranes and precision measurement and handling to place in position.

Types of prefabricated elements (linear, planar, boxes).

Box frame construction, also called cellular framing, or cross-wall construction, where individual element, or rooms, are set horizontally and vertically together to create an overall structural frame. Because the main weight of the building is carried through the cross walls, they must be sufficiently thick to carry their own weight as well as loads from above, and so the potential height of a structure built in this manner is limited. The most common application is in low apartment flats and similar buildings.

Glossary

Chamfering- a transitional edge between two faces of an object

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