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Moisture-proof CLT construction without a full temporary shelter

SWEDISH WOOD

Cover: Installing a CLT frame without a full temporary shelter.

Foreword

Because they are delivered with a low moisture content, structural elements in cross laminated timber (CLT) can be enclosed immediately. Elements in other materials may need to dry out before being enclosed. The moisture issue always needs to be addressed, but the method varies for different construction materials.

It is going to rain and maybe even snow during the construction process. The CLT elements are going to be exposed to moisture. But with the right handling, this needn't be a problem.

The vagaries of the weather can prevent efficient production flows on the construction site, whatever the material being used. It is not uncommon for rain and snow to cause extra work, delays and higher costs. According to a report by the Development Fund of the Swedish Construction Industry (SBUF), efficiency can quickly drop by 20—30 percent due to bad weather. Industrial construction risks being halted at the factory door.

One way to keep the industrial process going is to work with some form of full temporary shelter to create a kind of "field factory". There are plenty of good examples of how such shelters can help to cut construction times and lower costs. The choice of shelter should be decided early on in the project planning. The cost of a full temporary shelter can be set against the cost of the measures that have to be taken when building without a full temporary shelter.

The publication *Moisture-proof CLT construction without a full temporary shelter* provides guidance on how to handle CLT elements when building without a full shelter. It is intended to help project planners and builders achieve an industrial and damp-proof CLT build.

The publication focuses on various parts of the building, critical details and connections. It gives examples of how these can be damp-proofed and how the structural design can contribute to efficient construction in CLT.

The publication highlights the importance of communication, inspections and handling on site. It also provides knowledge about wood and moisture, as well as microbial growth.

The publication has been produced jointly by industry body Swedish Wood and the Swedish CLT manufacturers.

Further technical information and guidance on wood, CLT and timber construction is available on TräGuiden, **www.traguiden.se**, which is constantly updated with new knowledge and practical advice. TräGuiden is an extensive resource with tables, drawings and illustrations and available in English using Google Translate.

Information on wood, glulam, CLT and timber construction can also be found at **www.swedishwood.com**.

Stockholm, November 2022
Tomas Alsmarker and Johan Fröbel

CLT installation

Contents

Clear communication at every level

The key to a successful construction project is ensuring that the same messages are communicated at every level. It is vital that those planning and implementing the work are involved from the start, and understand how the issue of damp-proofing will be handled — and why. Lack of an overview, confused distribution of responsibilities and unclear communication put damp-proof construction at risk.

The construction sector tends to organise its work in project form, with different tasks divided up into different sub-projects. New people and different teams are brought together to resolve a specific task — their part of the project. Each has a focus on their own task and their business. Most errors occur in the interface between them, which is why communication needs to focus on the gap between the different areas of responsibility. There is much to be gained from ensuring that the people carrying out the different jobs on the construction site are also involved in the planning.

Basic knowledge about wood and moisture should be communicated to everyone who will be planning and doing the work. It is equally important to communicate how the choice of solution, good planning and preventive damp-proofing contribute to dry and efficient CLT construction. Inspection plans and checklists provide useful support, but above all it is about creating understanding and engagement, and being explicit about who is responsible for what.

The communication needs to involve clear, simple messages, such as:

- Remove free water and snow immediately.
- Sheeting used for damp-proofing must be breathable.
- Water that gets in must be able to get out.
- CLT elements with high moisture content must dry out.
- The surface moisture content should be no more than 18 % prior to being enclosed.
- Moisture — a priority point on the agenda.
- Check every day! It also rains and snows at weekends.
- To measure is to know.
- Snow and rain cost time and money if damp-proofing is not handled well.

The practical damp-proofing work is conducted by various parties, including planners, contractors and suppliers. The division of responsibility for different activities at different stages may vary, not least depending on the nature of the contract, but knowing who is responsible for what is crucial for successful damp-proofing work.

The developer will usually draw up a damp-proofing description containing relevant requirements, instructions, limit values and so on. The developer should employ a damp-proofing specialist to help in this work. In the case of a turnkey contract, the developer may choose to delegate this task to the contractor. However, overall responsibility still lies with the developer.

The developer should employ a damp-proofing expert to help set relevant damp-proofing requirements, draw up an inspection plan, conduct checks and follow-ups, review the design of the frame and the details, train those planning and implementing the project, and not least ensure that the message gets out to everyone concerned.

Ongoing CLT construction project.

Information in the damp-proofing description should be included in relevant documents. The contractor should draw up a damp-proofing plan outlining how the project will meet the requirements and instructions in the damp-proofing description. The damp-proofing plan should be worked into planning procedures, job descriptions and self-assessments.

Building Information Models (BIM) can provide useful support in the communication work. A shared BIM model provides a better overview and reduces the risk of information falling between two stools.

In Sweden, ByggaF is a methodology that sets out what should be checked, plus the procedure for the checks and documentation. The intention is to describe a standardised way of working in order to meet the damp-proofing demands of society and the developer. ByggaF contains templates and support for planning of damp-proofing, damp-proofing descriptions, damp-proofing plans and moisture inspections.

Good communication and knowledge saves money. The additional meetings will pay for themselves many times over in the form of less damage, fewer production stoppages, shorter construction times and higher quality.

CLT and moisture

$$u = \frac{\text{(weight before drying – weight after drying)}}{\text{weight after drying}} \times 100 = \text{moisture content in \%}$$

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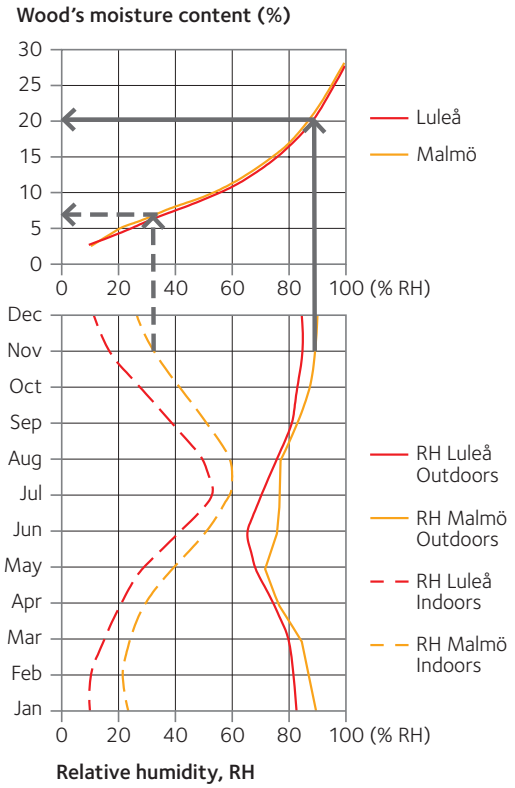


Figure 1 **Wood's moisture content in relation to relative humidity, RH**

The top section shows the correlation between ambient relative humidity (RH) and moisture content. The temperature also affects the correlation, but the effect is less than 1 % of the moisture content in the temperature range 0 – 20 °C.

The lower section shows the monthly average value for RH in the north of Sweden (Luleå) and the south (Malmö). The solid curves show RH outdoors and the dotted curves show RH indoors. The RH curves for indoors should be increased by around 18 % RH to account for the moisture added by a normal family (cooking, shower, laundry, breathing, perspiring and so on).

Example: What is the RH and average moisture content indoors in Malmö in November?
Following the black arrows, RH = 32 % and the moisture content 7 %. (Outdoors, the corresponding figures are RH = 89 % and moisture content = 20 %). At an RH of around 32 %, the wood's moisture content is thus around 7 %.

Wood constantly strives for a moisture content that is in balance with the ambient air. This means that wood is constantly shifting between absorbing and releasing water vapour. The moisture content of wood is expressed as the ratio between the water's weight in the moist wood material and the wood material's dry weight. The moisture content is measured using a moisture meter.

The higher the relative humidity (RH) in the air, the higher the moisture content in the wood. And vice versa. The air's relative humidity varies across the year. In summer the climate indoors and outdoors is more or less the same, while in winter the relative humidity of the air is significantly lower indoors than it is outdoors. The correlation between relative air humidity and the wood's moisture content is shown in *figure 1*.

The moisture fluctuations in wood caused by the ambient air are quite slow processes anyway, but this is particularly the case for mass timber structures in CLT. The surface material absorbs and releases moisture much faster than moisture can be transported into or out from the inner parts of the wood. The moisture content of the inner material has little impact on the risk of microbial growth.

An elevated surface moisture content increases the risk of microbial growth. These microorganisms are found everywhere in the air around us, but we can only see them with a microscope, or if a large enough quantity of them have begun to grow on a surface.

To begin growing, microorganisms need access to oxygen, nutrients, moisture and a sufficiently high temperature. All it takes to stop this is to remove one of the ingredients, such as moisture. Without access to moisture, the microorganisms are unable to grow. Wood should therefore only experience free water or elevated moisture content for short periods, and it should then have the opportunity to quickly dry out.

Microbial growth will not necessarily affect anything other than the appearance. The growth will stop as soon as the wood is allowed to dry out, and can be removed through sanding or blasting.

High relative humidity in outdoor air means that it takes longer for the wood to dry out by itself. The drying can be accelerated using dehumidifiers or by means of heating and increased ventilation. The drying must be done carefully, however, to avoid unnecessary seasoning checks. Increasing the heat too much and too early is not recommended.

CLT products are usually manufactured with a target moisture content of 12 %.

For a CLT frame protected from the weather in an outdoor climate, the moisture content of the CLT elements can vary between around 13 % (summer) and 17 % (winter).

Precipitation can cause too high a moisture content in the material. Rain or wet snow can quickly add large amounts of water to the structure, which risks pooling in holes and gaps, where it will take a long time to dry out.

Damp wood must not be enclosed. The maximum surface moisture content for enclosure should be 18 %. It is therefore important to carry out a last moisture check at this stage.

A suggested procedure for measuring using an electrical resistance moisture meter with insulated hammer electrodes is as follows:

- Check that the meter is calibrated using a calibration block.
- Measure the temperature in the wood with the integral temperature sensor or estimate the temperature with a separate thermometer.
- The temperature settings on the meter can then be set to the temperature of the wood. If the instrument does not compensate for temperature, the measurement value must be adjusted afterwards.
- Select wood type.
- Check the average moisture content by inserting the electrodes to the required measurement depth. Avoid measuring close to a layer of adhesive. Measure 300 mm from the end. Insert the insulated hammer electrodes into the face of the CLT, in the direction of the grain, and along an imaginary line running 0.3 times the width of the wood in from the edge. The measurement depth should be 0.3 times the thickness of the wood, *see figure 3*.
- When measuring the moisture content at the end grain, for example at the interface between wall and floor elements, measure 20 mm from the edge of the CLT. The electrodes should be inserted in the direction of the grain, *see figure 2*.
- The extent of the measuring is set out in the planning documents and the results are logged in the inspection plan. If the moisture content is higher than the desired level, regular checks should be carried out during drying until the desired moisture content is achieved.
- When measuring bulky items, it can be difficult to insert long electrodes. It may therefore be necessary to pre-drill holes and then tap in the electrodes for the last centimetre.
- When measuring the surface moisture content, press the conical jacket of the insulated hammer electrode tips down into the springwood of the surface by hand, so that half the jacket of the electrode tips makes an impression in the wood, going across the grain. Always take three measurements close to each other at the measuring point and then work out an average.
- The accuracy of handheld moisture meters is quite low, since the measurement depends on the density of the wood. A single measurement can only be assumed to lie within ± 2 percentage points of the true value. It is therefore necessary to take several measurements on different, nearby pieces of wood in order to determine the moisture content of a structural component.

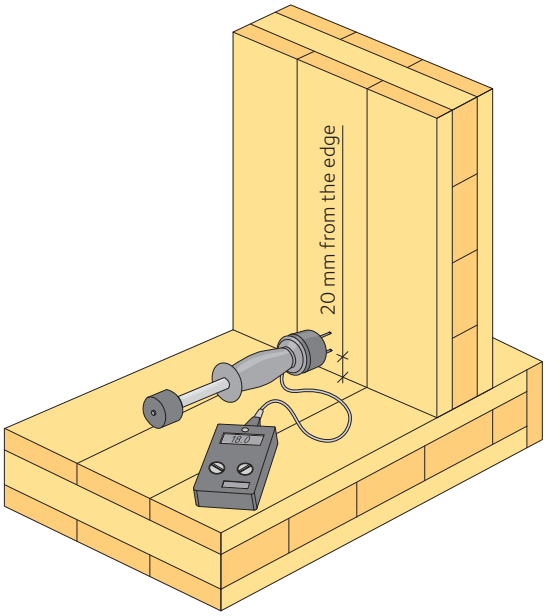


Figure 2 **Measuring moisture content at joint between wall and floor elements**

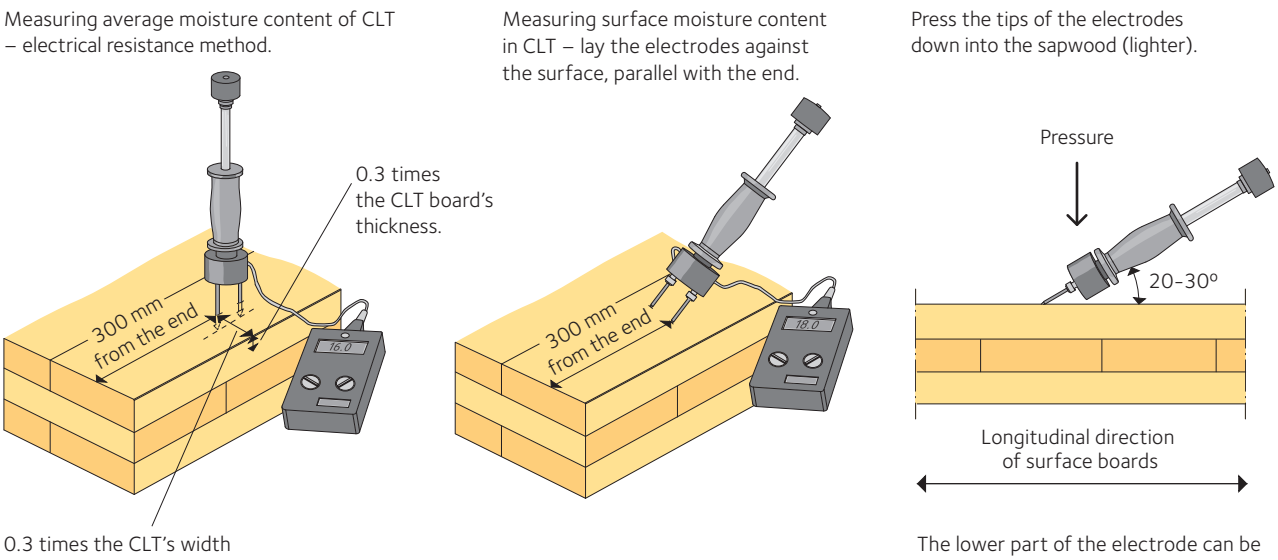


Figure 3 **Measuring average moisture content and surface moisture content**

Vacuuming up water from a floor.

Damp-proof CLT construction

Damp-proof CLT construction is about avoiding a high moisture load. CLT elements are delivered with a low target moisture content, usually 12 %, and can be enclosed immediately. Maintaining this low moisture content saves time and money.

The most critical point is to make sure that free water and wet snow are not left standing, either on horizontal surfaces or in joints and connections. Any water that gets in must be able to get out again, and damp wood must be able to dry out.

Try to use floor systems and outer walls as weatherproofing for the levels below. To quickly get a covering roof, the frame can be assembled in vertical sections, rather than storey by storey. Decisions on how to do this should be made as early as possible in the project planning process, as it can also affect stabilisation and the lifting and handling of construction materials.

Building the roof first means that it can be used to protect the floors below, with the roof being lifted as the frame is erected.

It is important to establish satisfactory drying conditions in the underlying levels.

The most important points to bear in mind are:

- Do not leave free water or wet snow standing on horizontal surfaces.
- Make sure end-grain wood, element joints and connections are damp-proofed.
- Water that gets in must be able to quickly get out.
- Damp wood must be able to dry out.
- Moisture checks are conducted on an ongoing basis.

Storage and handling

CLT elements are high-precision products that have a low moisture content when they are delivered to the construction site. To safeguard these properties during the production phase, the CLT elements must be protected from precipitation, sunlight, dirt and ground moisture.

Plan the deliveries according to the pace of production to keep storage times on site as short as possible. When the CLT elements are delivered, check that the packaging is intact and that the elements are free from soil and dirt. Damaged packaging should be repaired immediately. If moisture has entered through the damaged packaging, the packaging must be removed to allow the CLT to dry out.

Take random measurements of the CLT elements' moisture content, using an electrical resistance moisture meter with insulated hammer electrodes, at the time of delivery. A delivery of CLT normally has a moisture content of no more than 16 % on delivery from the CLT manufacturer.

Choose a storage place where water will not pool under the CLT elements. Asphalt or coarse macadam is a good underlay, as there is minimal risk of soil and dirt splashing up. The ground should also be cleared of snow. Do not place CLT elements where there is a risk of soiling and splashing from guttering or traffic, for example.

Keep a gap of at least 300 mm beneath the elements to ensure good ventilation and reduce the risk of soiling. Store the elements on a level surface with plenty of clean sticks between them to avoid deformations.

Cover the CLT elements such that air can get in without the formation of excessively high temperatures or condensation. Direct sunlight on unprotected CLT elements will quickly dry out the surface, increasing the risk of splitting and moisture-related movements. The splitting doesn't matter in purely static terms, but if it leads to water penetrating the wood during assembly, and not being able to get out again, moisture-related damage can occur. Make sure that the CLT elements are delivered in non-transparent packaging. This will protect against sunlight and reduce the temperature fluctuations inside the packaging.

Check the moisture content just before the CLT elements are installed. Continue with checks throughout the assembly phase. Check the surface moisture content before the CLT elements are enclosed. The surface moisture content should not exceed 18 % prior to being enclosed.

Prefabricated wall units being unwrapped for assembly

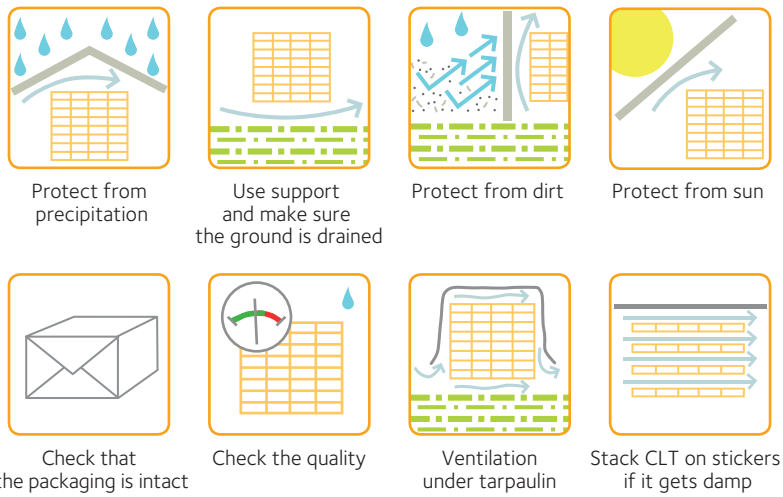


Figure 4 A few key principles for protecting CLT products

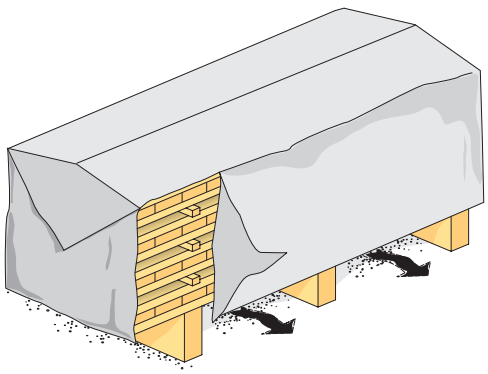
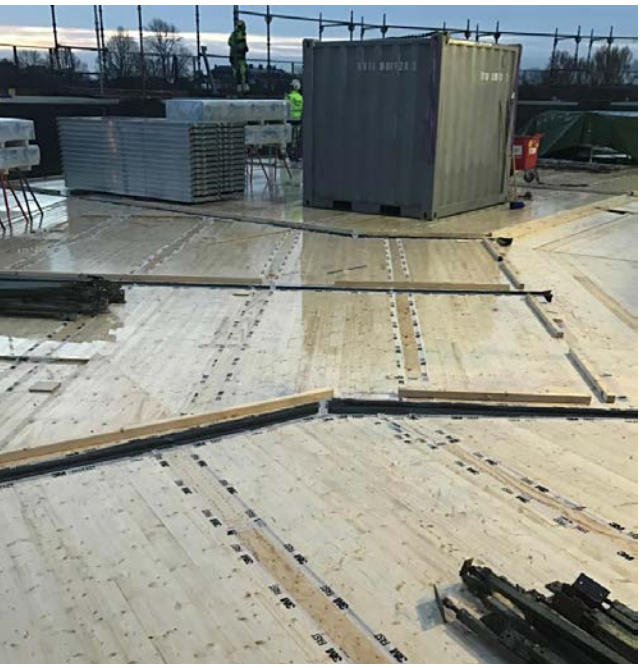


Figure 5 Storage of CLT on site

Floor systems



Floor system with taped joints.

The recommendation is to use the installed frame as weather protection, and in this context the floor system plays a crucial role as a temporary roof. As far as possible, the floor system should be planned as a “watertight roof”. Keep an eye out for concentrated water leakage.

Joints and connections should be designed so that the CLT elements can be connected, sealed and taped immediately after installation. Aim for smooth surfaces and connections with no nooks and crannies. Lifting holes and similar can be sealed with wood plugs or tape.

Check that the floor surfaces are kept clear of sawdust and rubbish, and from dirt and mud off shoes.

Rainwater and wet snow on the surface of a floor system should be removed immediately. A good way to do this is by scraping the water away with a rubber squeegee. A simple and effective method of channelling water away is to set up temporary drains. The holes for these should be prepared during the project planning phase. Make sure that the end-grain wood is protected in the cut-out hole. Snow can be collected up on laid out tarpaulins that can then be lifted away. Where you have small amounts of water lower down in the building, a wet-and-dry vacuum cleaner is a more suitable method.

There are also products and methods where the whole floor surface, including surrounding edges, is covered with full moisture protection, for example in the form of a self-adhesive breathable membrane.

Example of temporary drain between floors.

Walls

Just like the floors, the walls can provide useful temporary weather protection during construction. However, openings and joints need to be sealed. One option is to fit temporary weather protection on the scaffolding.

The wall elements can also be fully covered with a breathable membrane, using similar products and methods to those available for floors.

The horizontal end-grain surfaces are the most critical, so the tops of the walls should be protected from water and snow until the next floor system is in place. This can be achieved with a breathable tape or membrane, or temporary weather protection in the form of tarpaulins or similar. Exposed horizontal end grain also occurs in floors, windows, doors and shafts.

Free water, wet snow or water from a damp surface is absorbed by capillary action via the end grain of the CLT elements. When abutting concrete surfaces, the CLT elements should be placed on a damp-proof course that prevents moisture from travelling up to the wood. The wall elements may also be placed on spacers to handle irregularities in the foundation structure, while also reducing the risk of water being sucked up into the wood via capillary action.

Inner party walls require particular attention. These are often built as two separate wall elements separated by an air gap of 50 – 100 mm. This air gap runs more or less continuously through every level of the building. Rain or snow that gets in between the wall elements risks pooling in the bottom. It is therefore important that the top is covered after installation. If water does get in, it has to be able to dry out.

The vertical wall joints on the outside can be designed and sealed in the same way as for the floor structure. Choose simple solutions for rapid installation and smooth surfaces for simple and reliable sealing.

External wall with sealed floor edges and windows/doors.

Example of CLT elements that are taped for protection during installation.

Critical details

Short construction times, avoidance of drying time and rapid enclosure are all in the details. Much can be prepared in advance during the planning phase. Simple, sealed and smooth joints and connections create good conditions for rapid frame assembly and the addition of tape or membranes, etc.

The details and connections on which this guide wishes to focus are:

- Element joints
- Wall to floor joints
- Apartment balconies and access balconies
- Windows and door openings
- Stairwells and shafts
- Cut-outs.

At these details and connections, it is particularly important to check the moisture content regularly throughout the construction phase, in line with the established inspection plan.

Element joints

The most critical joints are those between the floor elements, as the floor needs to serve as a temporary “roof” during construction and it is flat.

Floor and wall joints should be designed so that the CLT elements can be connected quickly and simply. Aim for smooth surfaces that can rapidly be taped and sealed. This should be done immediately

Taped joint between floor elements and where the floor meets the wall.

after assembly. Remember that surfaces should be dry before taping for good adhesion.

Water and snow prevent the tape from adhering properly to the CLT elements. There needs to be a strategy in place to handle situations where taping cannot be done. This could involve a small-scale shelter and drying equipment to make taping possible.

If the joints in the top floor system are not correctly sealed, water could pool on the underlying levels. It is therefore important to keep an eye on the lower levels as the build continues. Additional tape may be applied as necessary.

Intersection of wall-floor and wall-foundations

Dirt can easily gather at the intersection between wall and floor, and this dirt retains moisture from rain and snow, which risks being transferred to the adjacent wood surfaces. Dirt makes it easier for water to penetrate into the gap below the wall elements and from there it can be sucked up by the wall's end-grain wood. To avoid water getting in between the wall and floor, the joint can be taped.

The CLT element should not come into direct contact with damp or wet concrete surfaces. When abutting concrete surfaces, the CLT elements should be placed on a damp-proof course that prevents moisture from travelling up to the wood. To solve this, the connection could be made on a raised plinth, thus reducing the risk of dirt, water or snow coming into contact with the wall element. The wall elements may also be placed on spacers to handle irregularities in the foundation structure, while also reducing the risk of water being sucked up into the wood via capillary action. Any bedding can be carried out once 2—3 storeys have been installed or once rain or snow can definitely no longer get to the concrete slab.

Wall elements raised on a concrete plinth with a damp course between them.

Apartment balconies and access balconies

CLT in apartment balconies and access balconies should be covered with a breathable membrane. To avoid water pooling against walls and posts, the sealing system should be designed to channel water away from these. The membrane should be folded a little way up walls and posts, and joints sealed with tape. The membrane should also be folded down and around the edges of the apartment balcony or access balcony to protect the end grain of the CLT. Tape the membrane to the underside of the CLT element.

Window and door openings

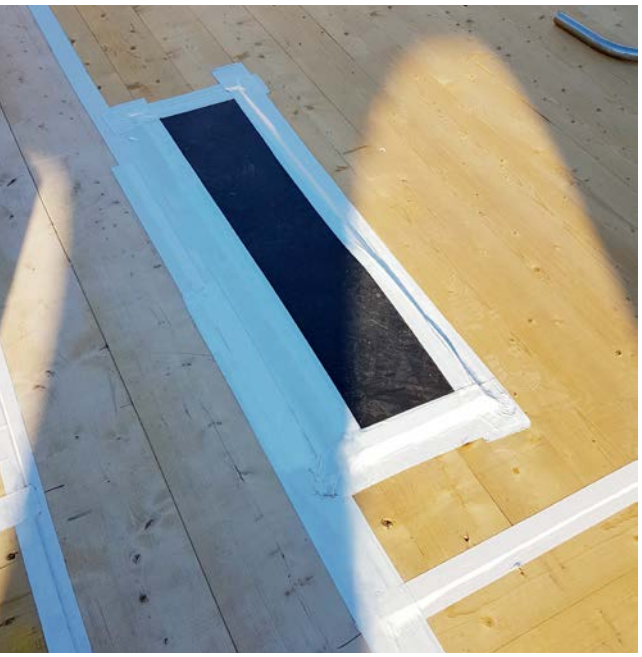
Openings for windows and doors are a major source of water leakage. The design of details and connections during planning is crucial. Ideally, no water should be able to get in, and any that does should be able to get out easily.

There is a large amount of end grain around openings. The easier and cleaner the connections, the quicker and better membranes and tape can be applied. Aim for clean and flat surfaces, with no nooks and crannies, as the best way to ensure easy and reliable sealing.

Door and window openings should be fully covered to stop snow and rain from driving in. The assembled frame will then be able to serve as weather protection and thus help with efficient damp-proof CLT construction.

Weather-proofed window opening.

Sealing a small hole with tape.



Sealing a large hole with a safety panel and tape.

Stairwells and shafts

Shafts run like vertical channels through the building. In a building with a CLT frame, the shafts will also usually be made of CLT elements.

The shafts are open all the way, so they need a temporary "roof" to prevent the ingress of rain and snow.

There is much to be gained from using such temporary roofs. They are like little local "hoods", with a gently sloping roof sitting on a small vertical collar. The collar is sealed against the floor with tape or a membrane that extends up the collar and out on the floor. The top of the roof is fitted with a waterproof membrane or tape.

If you decided not to work with a temporary roof, the point where the shaft wall meets the floor must be protected. This is because water that runs down the inside of the shaft wall must be prevented from running in between the floor and wall elements. The main focus should be on protecting the CLT end grain with a breathable tape or membrane. As far as possible, avoid fixings that puncture the tape or membrane.

Create a possible "escape route" for water that has got into the shaft and ended up down at the foundations.

Cut-outs

Cut-outs and plugs/seals are best dealt with by the CLT manufacturer, although they could also be done at the construction site, in which case the sawdust from the cutting should be removed.

Lifting holes should be sealed with a wood plug or tape immediately after assembly. If wood plugs are used, they should have a low moisture content and be protected against rising levels during storage. The wood plugs need to be able to swell slightly once they have been driven in for a tight seal.

Temporary sealing of smaller holes for installations or suchlike can be achieved using breathable tape.

Larger holes can be sealed with breathable membrane and tape, or with a covering sheet fixed to the CLT element and sealed round the edge with sealant, sealing strip or tape. Large holes covered with membrane should be provided with some form of protection against falling through to avoid accidents. The membrane should not be punctured by any such barrier.

Bibliography

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