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The Glulam Handbook

Planning and assembly of glulam structures

Volume 4

SWEDISH WOOD

The Glulam Handbook Volumes 1–3 are the result of a collaboration between glulam manufacturers and the industry organisations in Finland, Norway and Sweden. *The Glulam Handbook Volumes 1–3* are available in three languages – English, Finnish, Norwegian and Swedish. The content of these versions is adapted to meet Eurocode 5 and the associated national annexes, NA.

The Glulam Handbook Volume 4 is available in Swedish and English. It was produced by Swedish Wood and funded by the Swedish glulam manufacturers.

This publication is the fourth of the four-part Glulam Handbook.

- Volume 1 contains facts about glulam and planning guidance.
- Volume 2 provides calculations for the structural dimensioning of glulam.
- Volume 3 gives a number of example calculations for the most common glulam structures.
- Volume 4 provides knowledge on the planning and assembly of glulam structures.

Further knowledge, information and practical instructions on wood, glulam, CLT and wood construction are available on Wood Campus, **woodcampus.co.uk**, which is constantly updated with new knowledge and practical experiences. Wood Campus is an extensive resource with tables, drawings and illustrations.

Welcome to **woodcampus.co.uk**.

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

Stockholm, March 2024

Johan Fröbel
Swedish Wood

Cover: Assembly of riding school frame, Hallstahammar, .Sweden.

Contents

Installing glulam

As a construction material, glulam is easy to handle and comes into its own where construction timber is not strong or large enough and when you want to achieve a more dimensionally stable structure.

Building with glulam is basically like building with construction timber, but as the glulam elements are greater in size and weight, lifting equipment is often required.

1.1 General information on glulam installation

Glulam elements are fastened with steel or wood fixings that are nailed or screwed — normal work for timber construction workers on a building site, *see Chapter 7, On-site glulam modifications, page 35*.

Erecting a timber frame for a house is usually relatively easy to keep track of, but when the spans are larger, you lose some of the overview you have on smaller projects. Working with glulam becomes more of an assembly job, as the glulam elements have to be prefabricated before they can be lifted into place. Larger glulam elements require larger machines for transport and lifting. Working from a lift is also common when installing glulam, as scaffolding alone provides limited reach.

The project planner normally prepares the production drawings for a particular building. Correctly executed drawings enable the machining to be carried out by the glulam manufacturer, making it easier to assemble the individual glulam elements on the construction site.

Buying glulam that is not precisely cut means that you will have to perform cutting work on site. It is important that there is a place where this work can be carried out satisfactorily. Glulam beams are available in widths (b) from 42—215 mm as standard and the larger dimensions in the glulam range require special machinery to obtain good cut surfaces. This is important, not least, for achieving good alignment during installation.

Glulam manufacturers have good machining options, often using CNC (Computer Numerical Control) machines. These work with great accuracy, resulting in glulam elements with very precise dimensions, and they can process glulam elements up to about 20 m long.
The result can be a glulam element with very small dimensional tolerances, which makes it easy to produce a building according to the given dimensions.

With so many good hand-held tools on the market today, many glulam modifications can also be made on the construction site, *see also Chapter 7, On-site glulam modifications, page 35*.

Finishing work at a glulam manufacturer.

Glulam can be used for most types of buildings, from small to very large, but in general, glulam elements must be handled differently during installation. For example, if a glulam beam is going to be fully exposed, great care should be taken not to get it dirty. This can seem difficult sometimes, but it is not a problem if the installation work is planned and carried out correctly. A glulam frame that looks clean and fresh when the building is handed over should be a standard expectation for all the parties involved.

1.2 Handling glulam elements on the construction site

The use of webbing slings avoids edge damage to the glulam element and allows for good balance during the lift. When lifting large, heavy glulam elements, edge protectors should also be used.

Glulam elements are relatively light and easy to stack and lift. The packaging, made of recyclable material, should be kept on to reduce the risk of soiling during handling. It also protects against precipitation and the sun's UV rays.

The best method of lifting is with webbing slings, which are looped like a noose to prevent slipping during lifting. For larger glulam elements weighing more than 500 kg, edge protectors should be used to avoid damage to the slings and the glulam itself.

Important facts about a specific glulam element can be found on its accompanying label. Each glulam element should generally have a specific coded designation that is also used on the detailed drawing.

By adjusting the length of the lifting links, the glulam element can be made to follow the incline it will have in the finished structure, for example in monopitch or apex roof structures.

Straight glulam beams of even height are equally strong along their entire length, so they can be lifted with any arrangement of slings without damaging the glulam elements. Obviously, the slings should be positioned so as to ensure balance during the lift. In the case of curved glulam elements or glulam elements with varying dimensions or with large holes or notches, the position of the straps should be checked to minimise the risk of breaking the glulam element or causing an imbalance in the lift.

Even-height glulam elements have the same rectangular cross-section along their entire length, placing the centre of gravity in the middle. This makes it easy to position the webbing straps and achieve balance when lifting.

1.2.1 Weights of glulam elements

Some glulam manufacturers specify the weight of the glulam elements on the label, if the glulam was produced for a specific order. Weight information is not given on the stock range, which is often sold through timber and builders' merchants.

It is easy to calculate the weight of most glulam elements by hand or with a calculator. Here are some example weight calculations for glulam elements:

In Sweden, glulam is mainly made from spruce or sometimes pine, both of which have approximately the same density. On delivery, the glulam has a moisture content of 12 – 15 %, giving a density of around 470 kg/m^3. Pressure treated glulam has a density of about 600 kg/m^3.

There are different shapes of glulam elements, but it is easy to work out the volume of the main products and then the weight of the glulam element.

Volume is width × height × length, $b \times h \times L$, given in mm on the drawings. You preferably want a value in m³ as weight is usually expressed in kg/m³. The result of the calculation is in mm³, which must be divided by 10^9 to convert it into m³. This means shifting the decimal point 9 decimal places to the left.

Example: 90 × 405 × 6,000 = 218,700,000 mm³.
Moving the decimal point 9 decimal places to the left gives 0.2187 m³.

It may be easier to change the measurements to metres from the start, in which case move the decimal point 3 places to the left on each measurement. It should then look like this:

Example: 0.090 × 0.405 × 6.000 = 0.2187 m³.

For tapered and pitched roof beams in glulam, the average height must be calculated first and used as the parameter h in the volume calculation.

Calculate the weight of the glulam element by multiplying the volume by the density, 470 kg/m³, or 600 kg/m³ if it is pressure treated glulam.

Example: Glulam with a density of 470 kg/m³.

- A straight glulam beam measuring 165 × 1,305 × 17,000 mm weighs: 0.165 × 1.305 × 17.0 × 470 = 1,720 kg.
- A pitched glulam beam measuring

$$140 \times \frac{(720 + 450)}{2} \times 12{,}500 \text{ mm}$$

weighs:

$$0.14 \times \frac{(0.72 + 0.45)}{2} \times 12.5 \times 470 = 481 \text{ kg.}$$

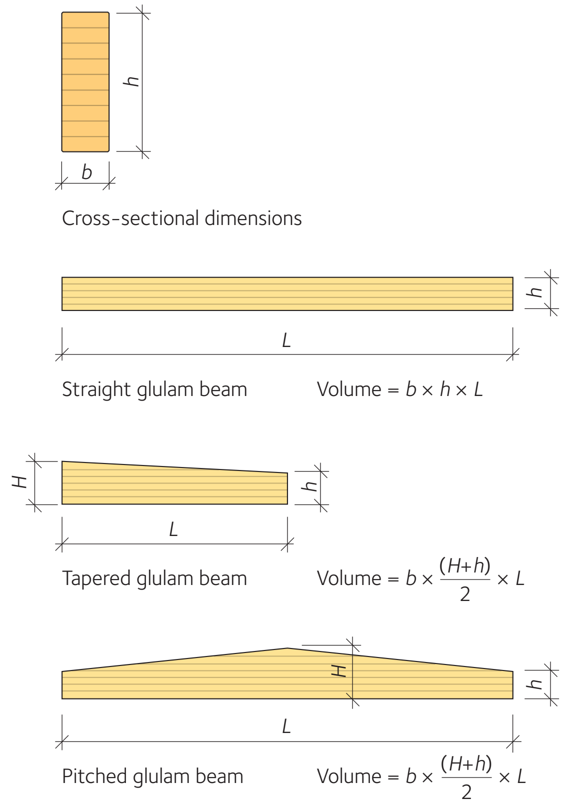


Figure 1.1 **Method of calculating glulam volume**

1.3 Transporting glulam

Glulam is mainly delivered to the construction site as individual glulam elements, generally on some type of truck. The type of vehicle is determined by the longest glulam element to be delivered, so consideration should be given early in the design process as to whether the glulam element can be joined on site.

Small-scale orders of glulam and element lengths up to 12 m are often supplied via timber and builders' merchants, who arrange delivery to the construction site. They will usually be able to get the glulam elements delivered by a truck with a crane to facilitate unloading and possible lifting. It will often be easier to get the goods at the desired time this way too, as the transport distance between merchant and site is usually short.

Some timber and builders' merchants will also be able to help lift certain glulam elements on site, if they can do it with the crane on the truck.

Glulam elements up to 12 m in length are delivered by truck and trailer. The truck can handle lengths of up to about 7 m and the trailer can handle up to 12 m. In practice, glulam elements with a length of less than 7 m are also loaded on the trailer, so you should expect the delivery to come on a truck with a trailer. The total vehicle length will then be about 24 m.

Truck unloading glulam delivery by crane.

Transporting long glulam elements by semi-trailer. In this case, escort vehicles were required.

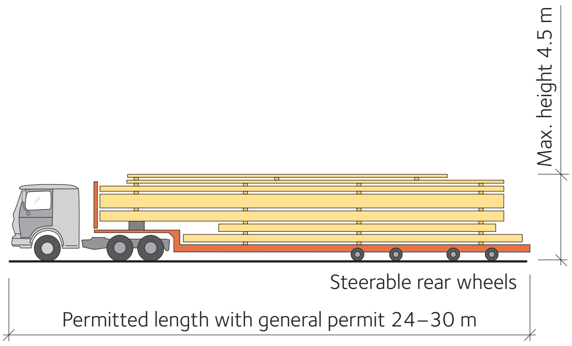


Figure 1.2 **Limit values for truck dimensions in Sweden**

Glulam elements with lengths over 12 m are transported on articulated semi-trailers. Some semi-trailers can be extended to over 30 m in vehicle length, allowing for the transport of glulam elements in lengths of 35 – 40 m.

Semi-trailers usually have steerable rear axles, which gives them good accessibility, but means they take up more space than a regular truck.

A fully loaded normal trailer holds around 50 – 52 m^3, which gives a load of about 24 – 25 tonnes.

Trucks with trailers often have a solid box compartment or open curtain sides. The glulam elements are usually loaded by forklift and placed so they are well protected in transit.

Since semi-trailers generally have open bodies, they can be loaded by forklift, bridge crane or mobile crane from above, which also makes unloading easier.

Glulam elements should be covered in transit during bad weather, but the packaging from the glulam manufacturer is mostly sufficient during transportation. If the glulam elements are not wrapped, the load should be covered with a protective tarpaulin or delivered in a covered vehicle.

To optimise transport both environmentally and economically, vehicles should be driven with as full a load as possible. However, do not order larger batches than can be received at the construction site.

A consideration when ordering glulam for delivery is that the road must be accessible to the vehicle required to transport the purchased goods.

Unloading is always the responsibility of the customer or the subcontractor employed to install the glulam structure.

The transport rules in Sweden are as follows, and most deliveries will fall within their limits:

Normal load width for road transport is 2.6 m on a vehicle of maximum 24 m in length, with an overall height below 4.5 m. This applies to both trucks with trailers and semi-trailers.

Load widths of 2.6 – 3.1 m and vehicle lengths up to 30 m may be driven on public roads with a general permit, but signage is required on the vehicle. Loads that are 3.1 – 3.5 m wide also require an escort vehicle. Wide loads of 3.5 – 4.5 m require a permit from the Swedish Transport Administration in each case, plus an escort vehicle.

Loads wider than 4.5 m require a case-by-case permit from the Swedish Transport Administration and must be accompanied by a road transport manager, usually with escort vehicles in front of and behind the truck.

Supplementary materials such as metal fittings are often delivered at the same time if procured by the glulam manufacturer – otherwise they may be supplied separately from selected metal fixing suppliers.

1.4 Unloading glulam

Acceptance checks, which must form part of an inspection plan under the Planning and Building Act (PBL), are carried out when unloading the glulam elements. The purpose of the check is to ensure that the delivery matches the order and the delivery note in terms of glulam elements and specialist fittings. Any damage to glulam elements and packaging should be noted at this point.

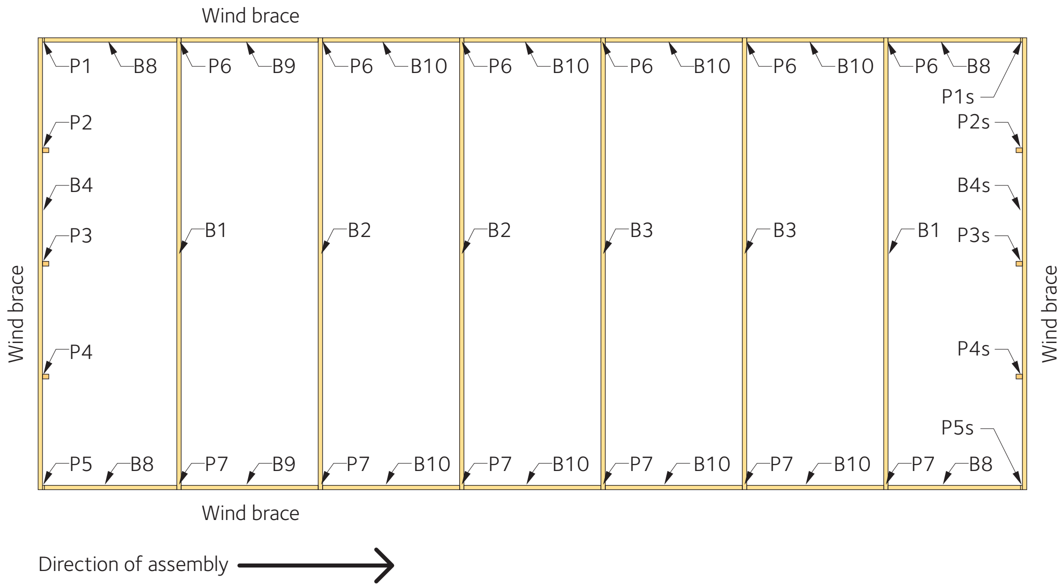


Figure 1.3 Example of a drawing with codes on the glulam elements. Knowing where the various glulam elements will be installed and in what order allows the glulam elements to be positioned so as to minimise extra movements on the construction site.

The inspection plan may provide for additional checks upon receipt, such as random testing of the moisture content of the glulam elements. The person responsible for receiving a glulam shipment should be familiar with what to check and how to handle the shipment.

Knowing where the various glulam elements will be installed and in what order allows the glulam elements to be positioned so as to minimise extra movements on the construction site. The person in charge of goods reception should study the codes on the structural drawings and the assembly order proposed on the assembly plan, so the glulam elements can be placed in the appropriate location for further assembly, without additional movements on site.

When unloading glulam elements, health and safety rules for heavy lifting apply. Not all drivers are trained in safe lifting and they are therefore not allowed to participate in the actual unloading.

Glulam elements are often loaded by forklift when transported on a truck with a trailer. Since the roof of the trailer cannot be lifted off, the glulam elements can only be unloaded with some type of forked loader, preferably from the same side of the vehicle as the loading.

There should be battens between the packets or glulam elements, creating space for the forks to be inserted. The clearance between the packages or glulam elements is usually only 70 mm, so the fork-lift operator must be precise and cautious to avoid damaging the glulam elements.

The packets vary in size and weight. Packets of 12 m or more in length require considerable space for unloading, so it is worth having a plan in place to ensure as little disruption as possible. Unloading often creates temporary interruptions to local transportation routes on a construction site.

Scissor lift and telehandler used in the assembly of a glulam frame.

Using a crane to unload glulam elements from a truck.

A crane is the fastest and best way to unload from a flat bed trailer. The crane has the advantage of being able to lift long glulam elements, and it can lift over vehicles and material stores, making it easier to position the glulam elements correctly on the construction site from the start.

Since large glulam elements do not come as packs, they can be unloaded individually. Curved glulam elements, such as arches and frames and some composite glulam structural elements, can generally only be lifted by crane during unloading and handling.

Each individual glulam element is marked at one end with a label that usually states its code plus other information, such as weight, strength class and dimensions.

Large and slim glulam elements should not be placed on edge as there is a risk of them falling over. If you want them on edge, the elements need to be braced on the side to keep them upright. Note that long glulam elements may need several braces, *see figure 1.4 below*.

If the glulam is to be installed soon after delivery, i.e. within a few days, it can be stored on smaller bearers than those prescribed in the chapter on *Handling glulam correctly on page 78 of The Glulam Handbook Volume 1*, although not less than 90 mm thick.

The bearers should be laid on a solid surface in a straight line so that the glulam elements do not bend during storage, with an overhang at the ends of no more than 2.5 m. The distance between the bearers should be max 4—5 m.

When laying down the first glulam element, check its alignment and adjust the position of the bearers if necessary, *see figure 1.5 below*. When stacking glulam elements, wooden spacers should be placed between them, and they should be positioned directly above the bearers in the same orientation.

Depending on the weather, glulam elements should be covered with a tarpaulin. Make sure there is ventilation under the tarpaulin, especially if the glulam elements will be left unattended for several days. If the glulam elements can be lifted directly to their final location in

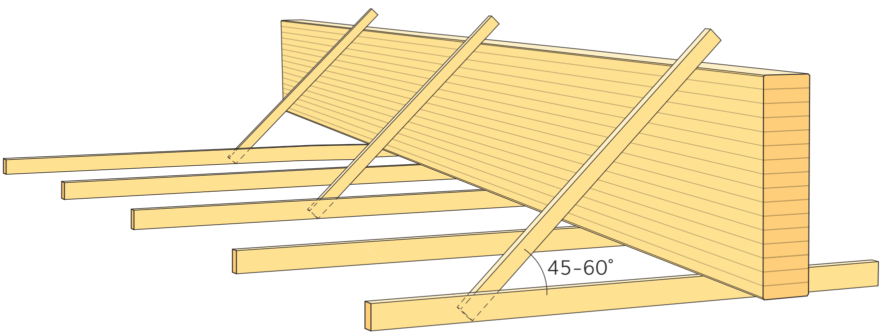


Figure 1.4 Suggested temporary bracing of glulam beam on edge in readiness for lifting

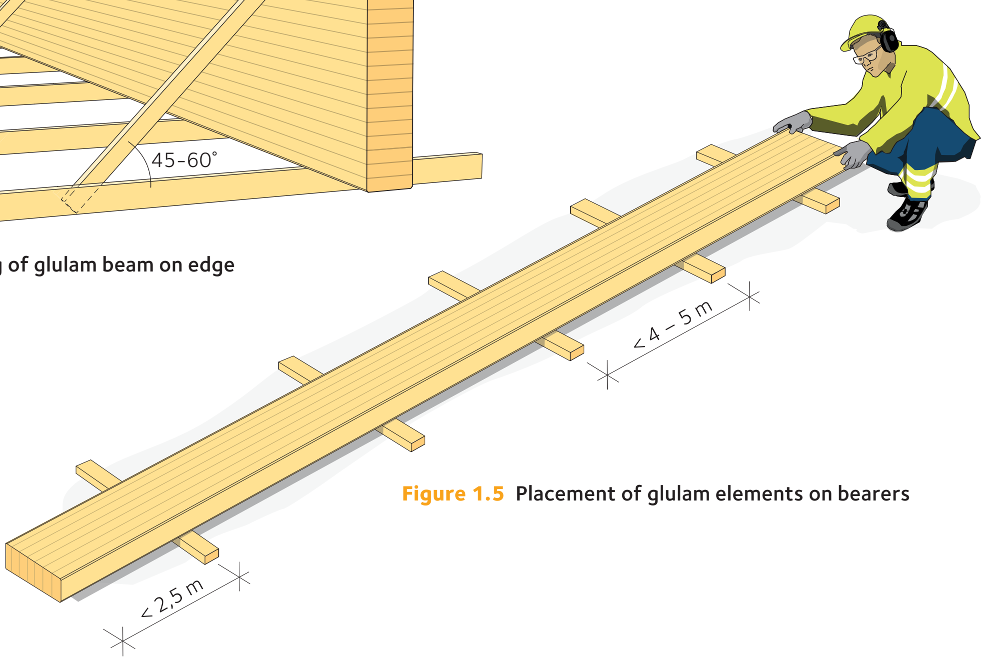


Figure 1.5 Placement of glulam elements on bearers

the building, this is the best solution, but in practice it is rarely possible. Do not stack too many different glulam elements together, as this means you may have to move some glulam elements to get the piece you need for the assembly. It is better to use several tarpaulins and have several smaller stacks for ease of installation.

1.5 Checklist for receipt of glulam deliveries

Plan the reception and assembly of glulam well in advance of unloading to avoid time-consuming extra movement. Here is a checklist:

- Plan the storage area for the glulam elements.
- Prepare the bearers and tarpaulins.
- Plan the storage to take account of the assembly order.
- Check that the number of glulam elements, dimensions and fittings match the order and delivery note.
- Check that the glulam's packaging is intact.
- Check the glulam delivery, noting any visible damage. Check that the glulam is free from dirt. Check the strength class and labelling against the order and delivery note.
- Clearly and systematically mark individual glulam elements and fittings for ease of installation.
- Drain any moisture from inside the packaging by cutting it open on the underside.
- If required in the inspection plan, measure the moisture content of a number of glulam elements using an electronic resistance moisture meter with insulated hammer electrodes to get an indication that the correct moisture content has been delivered. Moisture content measurement is rarely necessary if the delivery comes directly from the glulam manufacturer. If any glulam elements have too high a moisture content or are damaged, this should be reported to the supplier immediately.

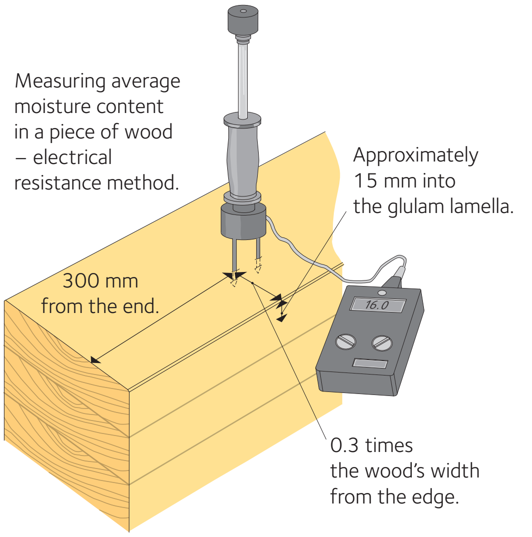


Figure 1.6 **Measuring average moisture content in a glulam element using an electrical resistance moisture meter with insulated hammer electrodes**

1.6 Checklist for glulam storage

Glulam elements loaded onto a trailer for delivery to the construction site.

When storing glulam outdoors for around 1–3 weeks on the construction site, the instructions for storage should be followed, *see The Glulam Handbook Volume 1, Handling glulam correctly, page 78*.

Long-term storage of glulam elements – storage longer than three weeks outdoors on site – should be avoided. If glulam has to be stored for more than about three weeks on site, extra measures should be taken, including regular checks.

Here is some general advice on the short-term storage of glulam:

- Never place glulam elements directly on the ground.
- Use clean bearers that raise the glulam elements at least 90 mm off the ground or floor, if possible even higher, and provide good air circulation around the elements.
- The substrate should be dry and level so that the glulam elements do not sag or become distorted. Make sure there are enough bearers to prevent the glulam bending.
- Place clean spacers of 45–95 mm thick timber between the glulam elements and position the spacers vertically above each other. The thickness of the spacers depends on how the specific glulam elements will be lifted. A forklift requires at least 70 mm.
- When stored outdoors for a short period of time, the glulam elements are to be protected by tarpaulins laid onto clean timber joists so that adequate ventilation is obtained under the tarpaulin. Make sure that the tarpaulin does not touch the glulam anywhere. Do not let the tarpaulin reach all the way down to the ground.

Note that if the glulam has become damp, it must be allowed to dry out slowly to prevent cracking. It is normal for cracks to appear as a result of the drying that occurs during the first few years after installation, but these are generally so small and superficial that they are not a major concern.

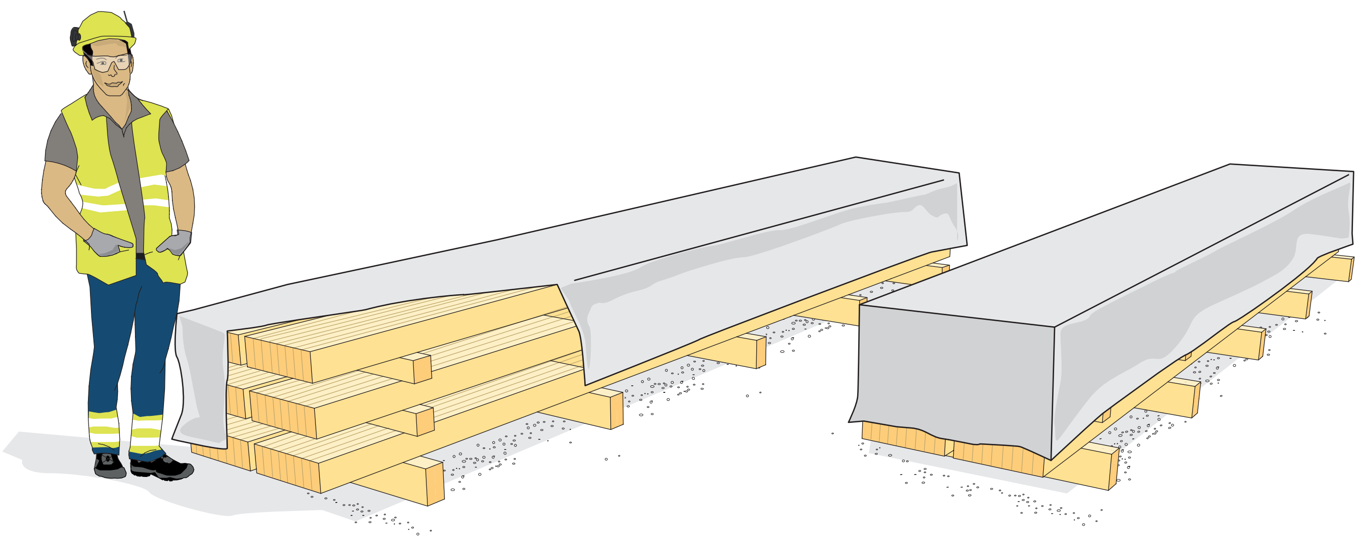


Figure 1.7 **Example of short-term, on-site storage, maximum 3 weeks**

Designing a glulam frame with reference to its assembly

2.1 Eurocodes and Boverket's regulations for building works

The design of any building must take into account the loads that may occur during the construction phase. The requirements in this regard are specified in the applicable standards:

- SS-EN 1990, Eurocode 0: Basis of structural design.
- SS-EN 1991, Eurocode 1: Actions on structures.
- SS-EN 1995, Eurocode 5: Design of timber structures.

These are the standards that apply in Sweden, along with Boverket's building regulations, general recommendations and series of provisions on the application of European construction standards (EKS). The requirements set out in the Eurocodes and Boverket's EKS provisions deal with structural safety, robustness and usability.

Under the structural safety requirements, a building must be designed and constructed to withstand all the stresses and strains that can reasonably be expected during its construction and use.

Consideration should thus be given to temporary loads from the activities required for the construction of the building, temporary storage of materials, etc. The focus is on the safety of people, the building and the contents of the building.

The loads to be used in calculations are explained in Eurocode 1 and it is also important to check whether building components are subject to different loads during the construction phase than in the finished building.

This is achieved through appropriate design and construction choices and by carrying out checks during both the design and construction phases.

It is also necessary to consider wind loads on equipment used during installation, such as scaffolding, lifts and temporary shelters.

Where operations are of short duration, for example lifting, a maximum permissible wind speed should be determined for the operation.

When raising glulam arches, frames and suchlike from horizontal to vertical, ensure that warping of the glulam elements is avoided.

Also avoid overloading during storage, transportation and assembly of structural components.

Accidental loads, such as impacts from cranes and local failure of temporary supports, including dynamic effects, also need to be considered during the construction phase if they might cause the collapse of structural elements.

Assembling the glulam roof frame for the Brigade Museum in Karlstad, Sweden.

An inspection plan for glulam installations should include checks on the design, manufacture and condition of the glulam elements, both before and after arrival at the construction site:

- Checks on transportation, storage and handling of all materials.
- Checks on joining and assembly.

A check on the final result should also be carried out, for example by visual inspection or test loading.

An inspection plan for the construction project, in compliance with the Planning and Building Act (PBL), must contain items covering these areas. Responsible contractors, including subcontractors, must verify that these controls have been carried out by means of their own inspection plan.

2.2 The Swedish Work Environment Authority's provisions

The Swedish Work Environment Authority's regulations on Building and civil engineering work (AFS 1999:3) and on BAS-P/BAS-U coordinators apply to all areas of a construction site.

The BAS-P coordinator is responsible for the work environment during the initial planning and design phase, while the BAS-U coordinator takes over responsibility for creating a safe work environment as the construction project moves from planning and design to execution.

Rules that apply generally to machinery and personnel are not included in *The Glulam Handbook Volume 4*. It is assumed that the personnel on the construction site have the right training for the tasks they are to perform and that the machinery used meets the applicable requirements.

The risks inherent in glulam installation can vary depending on the type of structure to be erected and the nature of the construction site. However, there are essentially three main risk areas:

- Falls from height.
- Heavy lifting.
- Passing traffic.

Risk assessments are used as the basis for drawing up accident prevention measures, which must be recorded in an assembly plan and a work environment plan for the construction project.

Coordination responsibilities under BAS-P and BAS-U do not in any way detract from the health and safety responsibilities of each individual contractor on the construction site.

Building and civil engineering work (AFS 1999:3), published by the Swedish Work Environment Authority.

Temporary bracing of glulam frames

The glulam frame will need to be braced from the installation of the first glulam element until the permanent stabilisation system is fully in place, so the extent and duration of the bracing can vary.

Temporary bracing has multiple tasks and must be able to withstand changing loads as the installation progresses:

- Bracing should ensure that individual elements are correctly fixed in terms of location, orientation and straightness.
- The bracing must be designed and constructed to withstand the loads to which the building is exposed during the construction phase — loads on the individual glulam elements but also loads that act on other elements in the building before permanent stabilisation is complete.
- The bracing must be carried out in such a way that it does not impede the installation of additional frame elements, roof and wall purlins, load-bearing metal fixings, etc. It should not be necessary to dismantle parts of the temporary bracing in order to install such elements.

3.1 Practical considerations

Assembly supports available on the market that can be handled without lifting aids are limited to about 5 – 10 kN of axial force at lengths of 3 – 5 m.

Glulam beams or assembled glulam roof trusses should therefore also be braced between supports to prevent glulam beams or roof trusses from bowing outwards, an effect best achieved with wire rope, cables or straps. This fixes the glulam frame more securely in place and takes some load off the assembly supports, meaning that fewer are needed and they are easier to handle.

Temporary bracing when installing glulam frames.

3.2 Design loads on glulam frames in the construction phase

Permanent wind braces in completed machine hall with glulam frame.

This section focuses on glulam halls and provides the information a structural engineer needs to calculate loads and their actions on a normal glulam hall-type building during a "temporary design situation", i.e. a design situation that is relevant for a much shorter period of time than the intended service life of the structure. The design situation dealt with in this section is load-bearing structures during assembly.

The primary loads to be considered in the construction phase of a structure are:

- **Permanent load**, G, i.e. the self-weight of the glulam frame.
- **Variable load**, Q, i.e. primarily snow load and wind load.

This section deals only with the loads that can lead to lateral instability of the frame, which is most often the cause of failures during the assembly phase. Thus, only wind loads are considered in this section. For normal spans and normal slenderness of the structural members, second-order actions caused by deviations from the ideal geometry can generally be ignored in stability checks of lightweight frames during the construction phase.

3.2.1 Wind actions on structures with reference to Eurocode 1

The resultant force on a structure or part of a structure caused by wind can be determined as follows according to *SS-EN 1991-1-4, section 5.3*:

$$F_w = c_f \times q_p(z) \times A_{ref}$$

where:

c_f is the coefficient for the force on the structure or part of the structure, *see section 3.2.2 below*.

$q_p(z)$ is the characteristic velocity pressure for the reference height z, *see section 3.2.3, page 17*.

A_{ref} is the reference area of the structure or part of the structure, i.e. the area being subjected to the wind.

3.2.2 Coefficient c_f with reference to Eurocode 1

Coefficient cf according to *SS-EN 1991-1-4, section 7.4.3*:

The force coefficient, c_f, gives the resulting wind load on the structure or part of the structure. For glulam posts and beams during assembly, one can assume:

$$c_f = 1.8$$

3.2.3 Characteristic velocity pressure with reference to Eurocode 1

Characteristic velocity pressure $q_p(z)$ in N/m² according to *EN 1991-1-4, section 4.5*.

The characteristic velocity pressure, $q_p(z)$, at height z in metres, can be determined as:

$$q_p(z) = c_e(z) \times q_b$$

where:

$c_e(z)$ is the exposure factor, *see figure 3.1*.

q_b is the reference mean velocity pressure in N/m² according to $q_b = 0.625 \times v_b^2$. For the design of load-bearing structures during erection, the reference wind speed v_b can be defined as a function of season, at a height of 10 m above the ground in terrain type II:

$$v_b = c_{season} \times v_{b,0}$$

$v_{b,0}$ is the base value of the reference wind speed (the characteristic mean wind speed for 10 minutes) in m/s determined at 10 m above the ground in terrain type II, *see figure 3.2*.

c_{season} is the season factor, *see table 3.1*.

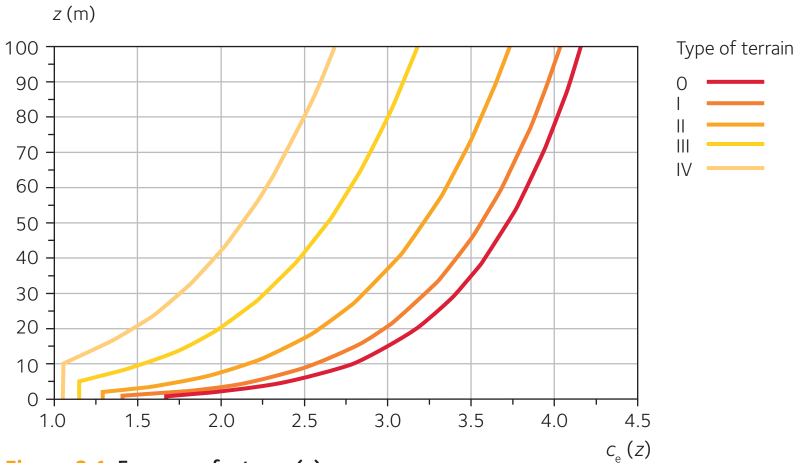


Figure 3.1 Exposure factor $c_e(z)$

Table 3.1 Season factor c_{season} for the months of the year. If installation runs over several months, the highest value applies.

One month annually	c_{season}
January	1.00
February	0.83
March	0.82
April	0.75
May	0.69
June	0.66
July	0.62
August	0.71
September	0.82
October	0.82
November	0.90
December	1.00

Source: SS-EN 1991-1-4

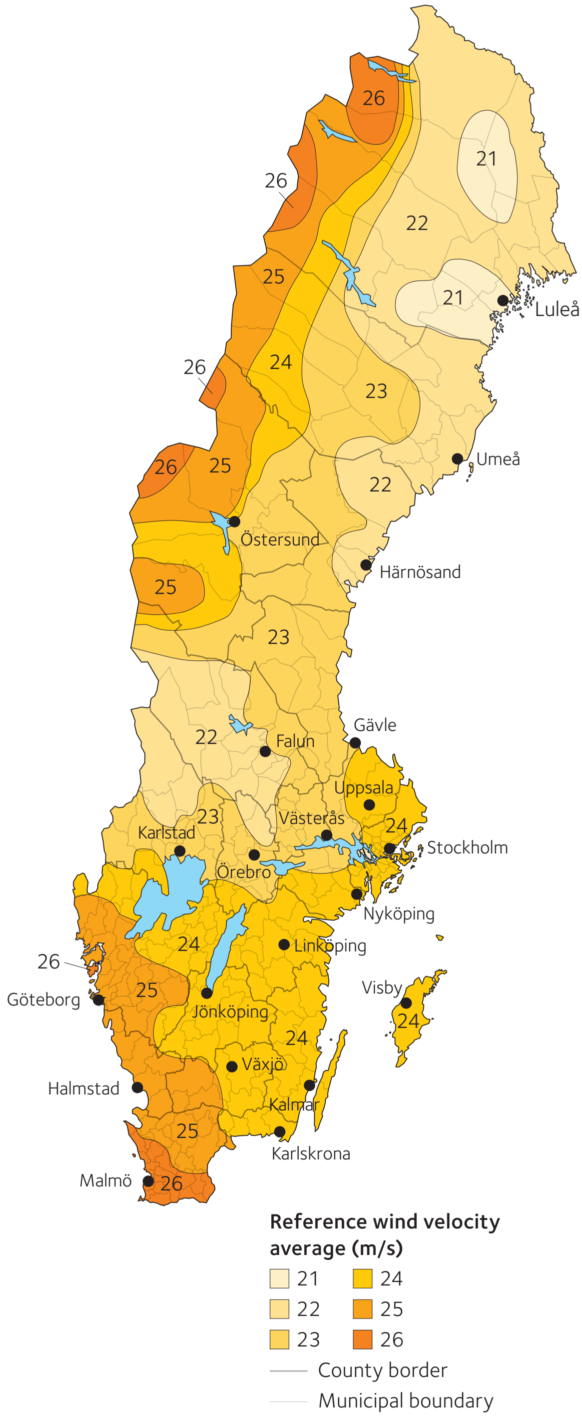


Figure 3.2 **Reference wind velocity according to Boverket's building regulations, EKS 10.** Reference wind velocity basic value $v_{b,0}$ in m/s determined at 10 m height above ground in terrain type II.

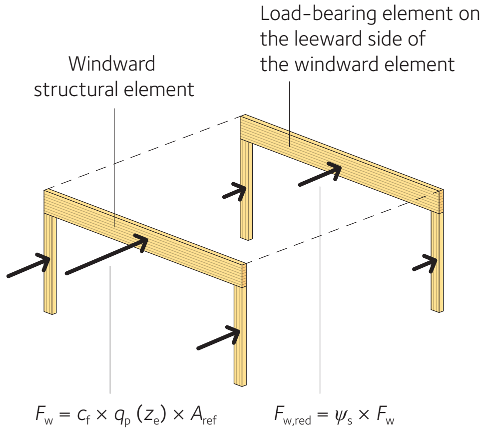


Figure 3.3 **Definition for windward and leeward structural elements**

3.2.4 Shelter factor with reference to Eurocode 1

The shelter factor should be taken into account for structural elements that are in the lee of the windward structural element, as set out in *SS-EN 1991-1-4, figure 7.20*. If the structural element in question is to the leeward side of the windward structural element, which is the same height or higher, this can be taken into account by multiplying coefficient c_f by a reduction factor, or shelter factor ψ_s.

With structural elements of glulam halls, if the windward structural element is as high as or higher than the leeward structural element, one can assume $\psi_s = 0.3$.

3.3 Stability check of glulam frame during the construction phase – example

Figure 3.4 shows the main drawing of an indoor arena for a riding school in Gothenburg in open terrain without obstacles, terrain type I. The structure consists of three-hinged glulam trusses reinforced with steel ties (in *Example 2, page 66* referred to as tied glulam trusses) and supported by braced glulam posts, all spaced 6 m apart. Construction is to be carried out in safety class 3 and installation is planned to take place between March and May.

The most sensitive part of the installation is likely to occur when the trusses in lines 2 and 3 have been erected and the permanent wind braces between them have not yet been installed, *see figure 3.5, page 19*.

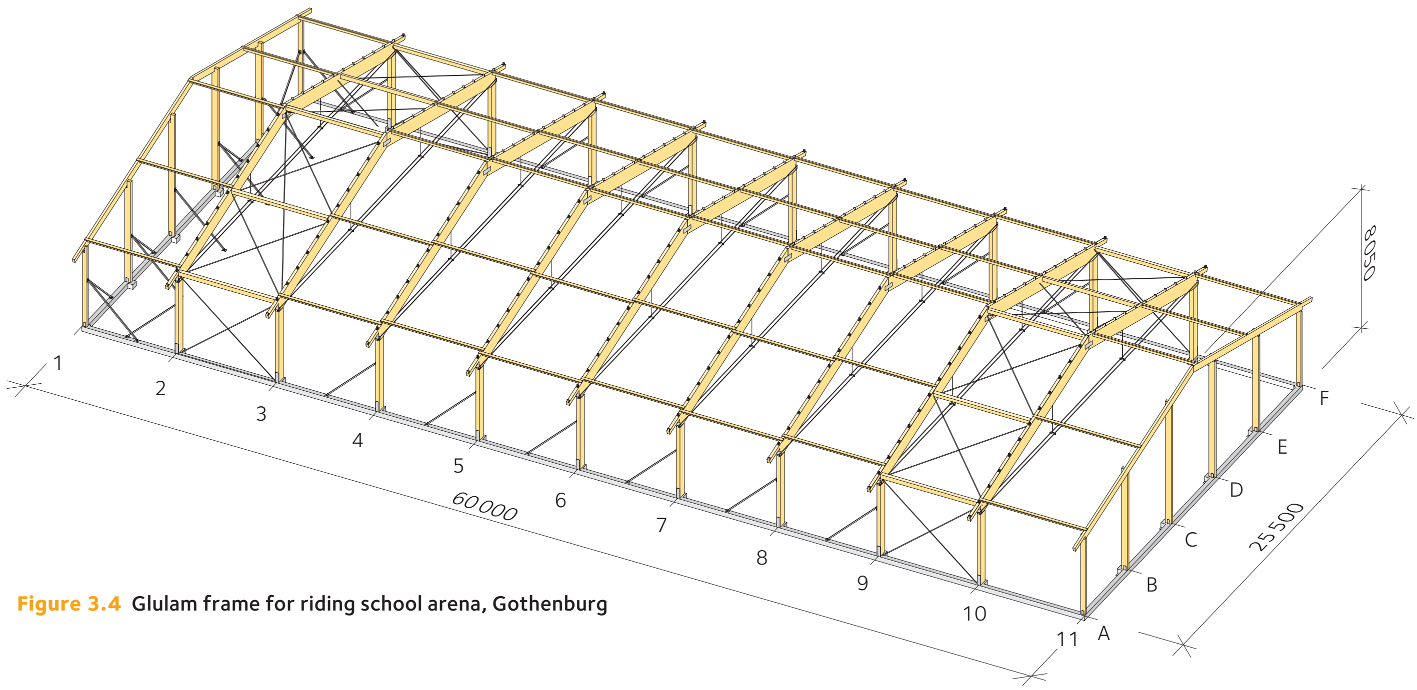


Figure 3.4 **Glulam frame for riding school arena, Gothenburg**

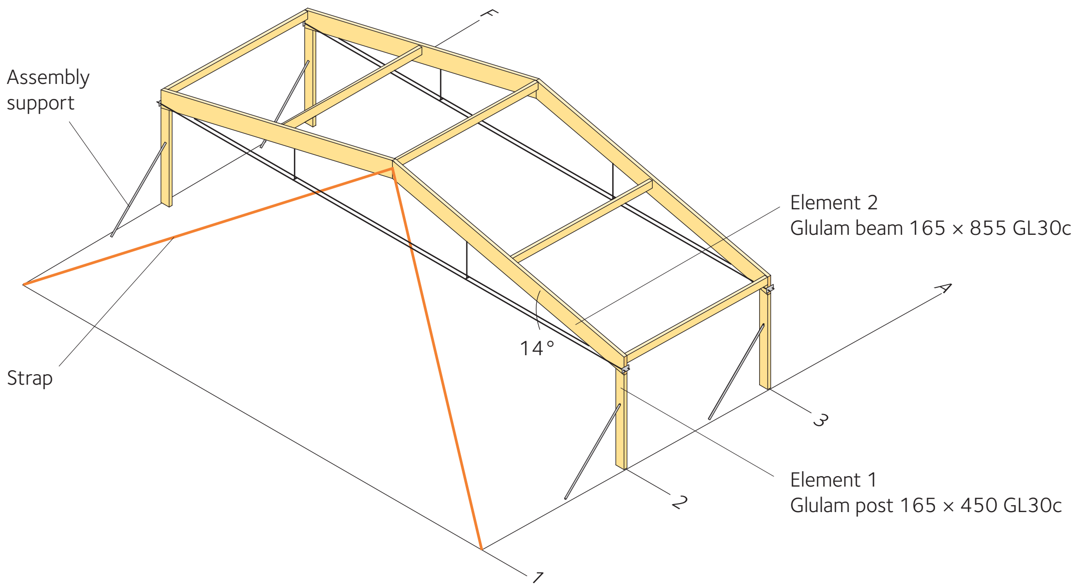


Figure 3.5 The construction phase when the load during temporary bracing is assumed to be highest – the most sensitive moment when the permanent wind braces have not yet been installed

The axial force in the bracing elements depends to some extent on the stiffness of the various load-bearing parts, both temporary and permanent. The assumption of inelasticity in the bracing elements, i.e. bracing elements with infinite axial stiffness, normally gives reasonable results and can usefully be applied in the manual calculation procedure.

In this section, the calculations have been performed using a finite element-based framework analysis program. The static model, corresponding to the above example during the construction phase, is presented in *figure 3.6*.

Note that there are four straps connected to the ridge of the three-hinged truss in line 2. In general, each strap is tightened with a given tension, from the ridge to a fixing placed at the foot of the glulam post in the adjacent line.

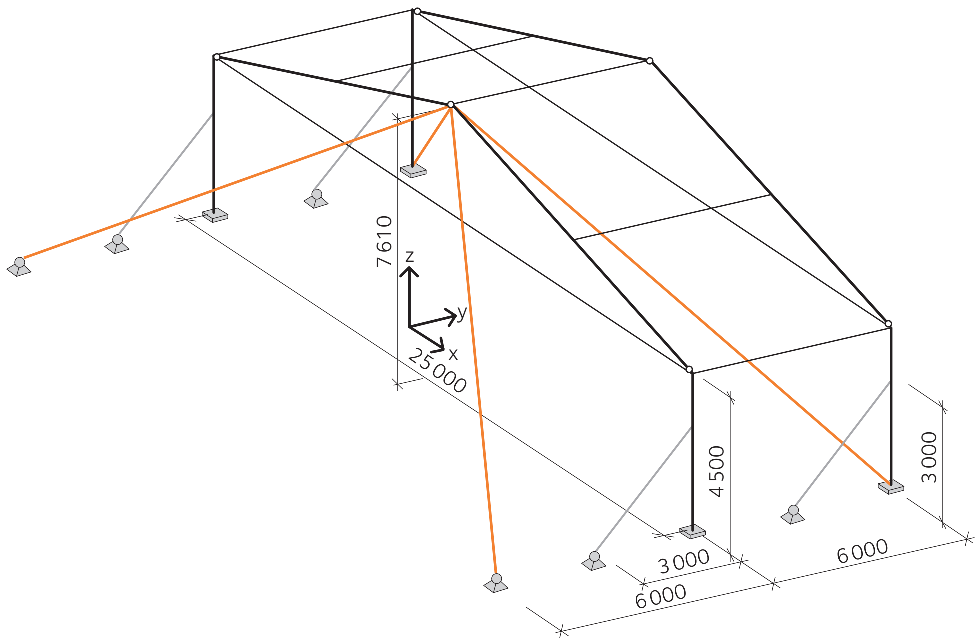


Figure 3.6 The static model in the finite element program. The post feet are fixed for rotation about the y-axis and hinged for rotation about the x-axis.

Glulam hall during construction.

For moderate wind loads, it can be assumed that all four straps help to take up the wind load, which acts perpendicular to the plane of the three-hinged trusses. The tensioned straps are able to do this because they tend to be taught and therefore, under compressive loads, they will take up loads by reducing the original pulling force, known as the tension force. However, the magnitude of the tension force at the time of fitting the strap is often uncertain, which means that if the tension force is not sufficiently large at higher wind loads, there is a risk that the compressive force in the strap will be greater than the tension force. In such a scenario, two of the straps become inactive. For this reason, the calculation assumes that only two of the four straps help to take up the wind load.

Wind load

- Characteristic velocity pressure $q_p(z)$

$$q_p(z) = c_e(z) \times q_b$$

Exposure factor $c_e(z)$ can be obtained from the table below, *see also figure 3.1, page 17*.

Structural element	Height (m)	$c_e(z)$
1	2.3	1.8
2	7.6	2.3

- Reference wind velocity v_b

$$v_b = c_{season} \times v_{b,0}$$

$v_{b,0}$ = 25 m/s (Gothenburg)
c_{season} = 0.82 (highest value selected for the period March – May)
v_b = 0.82 × 25 = 20.5 m/s

- Reference velocity pressure q_b

$$q_b = 0.625 \times v_b^2 = 0.625 \times 20.5^2 = 263 \text{ N/m}^2 = 0.263 \text{ kN/m}^2$$

Structural element	Characteristic velocity pressure $q_p(z)$ (kN/m²)
1	1.8 × 0.263 = 0.47
2	2.3 × 0.263 = 0.60

- Wind load on the different structural elements F_{wi}

$$F_w = c_f \times q_p(z) \times A_{ref}$$

Structural element	c_f	$q_p(z)$ (kN/m²)	A_{ref} (m²)	F_w (kN)	q_w (kN/m)
1	1.8	0.47	0.450 × 4.5 = 2.03	1.7	1.7 / 4.5 = 0.38
2	1.8	0.60	$\frac{25}{2 \times \cos 14°} \times 0.855 = 11.01$	11.9	11.9 × cos14°/ 12.5 = 0.92

In the case of the truss in line 3, which is leeward of the truss in line 2, the wind load can be reduced by a reduction factor, referred to as the shelter factor ψ_s. In this case, you can set $\psi_s = 0.3$.

Figure 3.7 shows the finite element model with the wind loads, in the form of uniformly distributed line loads q_{wi}, applied to the main structure.

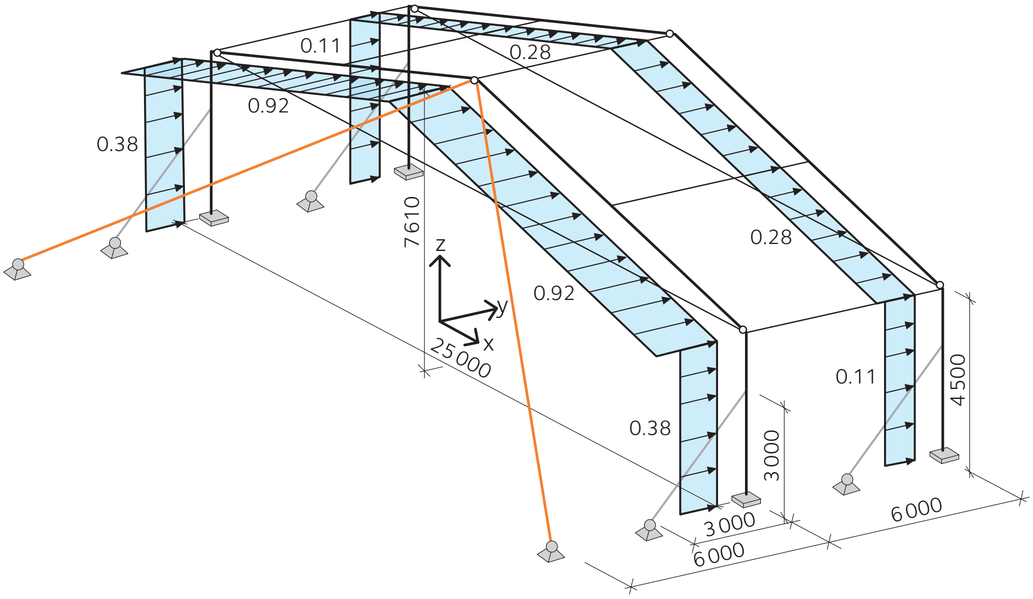


Figure 3.7 The finite element model with associated wind loads. Note that: a) only two of the four straps have been used in the model and b) the ratio between the wind load for the windward truss and the leeward truss is $\psi_s = 0.3$.

3.3.1 Design of temporary bracing and its fixings

The normal forces in the temporary stabilising elements, caused by characteristic wind load on the glulam trusses in lines 2 and 3, are shown in *figure 3.8*. For the simple reason of presenting the results more clearly, the finite element model for glulam posts and three-hinged trusses has been deactivated in *figure 3.8*.

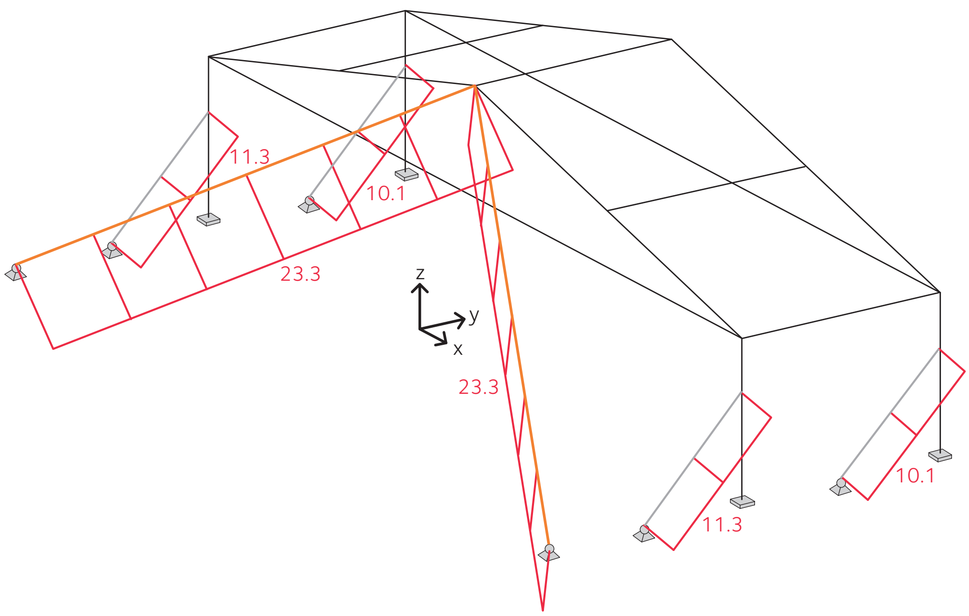


Figure 3.8 Numerically calculated normal forces in the temporary stabilising elements

The corresponding design normal forces in the stabilising elements are obtained by multiplying the characteristic load value by the partial load coefficient γ_F. Safety class 3 has been adopted here, γ_d = 1.0.

Design normal force in the strap (tension):

$$N_{1,d} = \gamma_F \times N_{1,k} = 1.5 \times 23.3 = 35 \text{ kN}$$

Design normal force in the assembly support (can be both tension and compression, depending on the location of the support):

$$N_{2,d} = \gamma_F \times N_{2,k} = 1.5 \times 11.3 = 17 \text{ kN}$$

Note that consideration should also be given to sectional forces and moments arising in the various load-bearing parts of the truss during installation. *Figure 3.9 a) – c), page 23*, shows the diagrams for normal force, shear force and moment in the windward truss for the load case in *figure 3.7, page 21*.

For example, the shear force may in some cases be a design factor for the connections between different structural elements, for example glulam beams and posts.

In larger glulam structures, bending moments around the weak direction in glulam posts and/or glulam roof trusses may also be a design factor. In these cases, several bracing points in the structure or, to some extent, the choice of a thicker glulam cross-section may be a suitable alternative.

Machine hall with glulam frame.

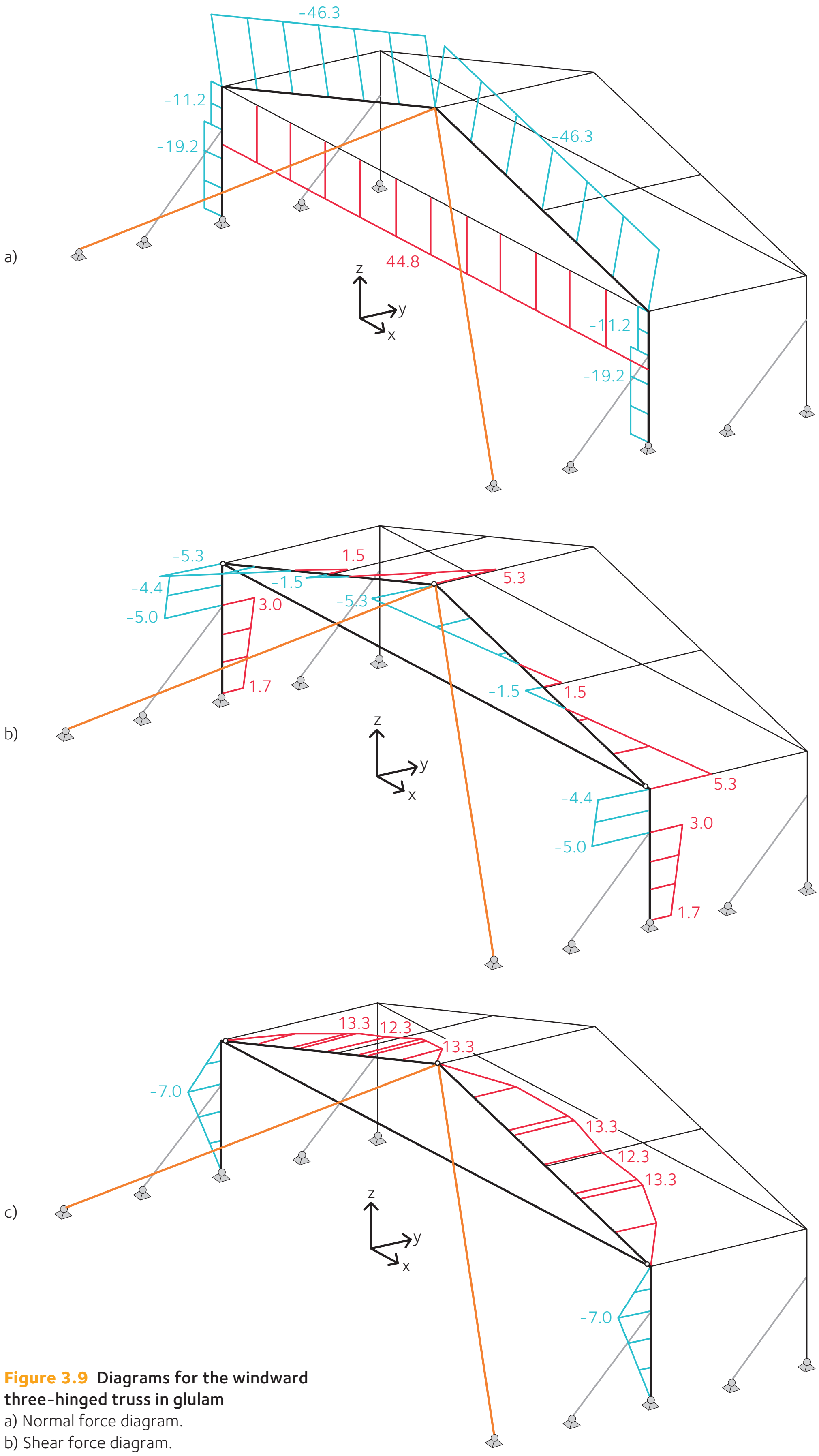


Figure 3.9 **Diagrams for the windward three-hinged truss in glulam**
a) Normal force diagram.
b) Shear force diagram.
c) Moment diagram.
Load case, *see figure 3.7, page 21.*

AMA Hus 18 and RA Hus 18
Allmän Material- och Arbetsbeskrivning (AMA) is a series of reference books on construction published by AB Svensk Byggtjänst. It is supplemented by RA (Råd och Anvisningar/ Advice and Instructions), and provides useful assistance in drawing up specifications for a tender and construction documents for contractors. AMA sets out requirements concerning materials, procedures and the end result for common building tasks.

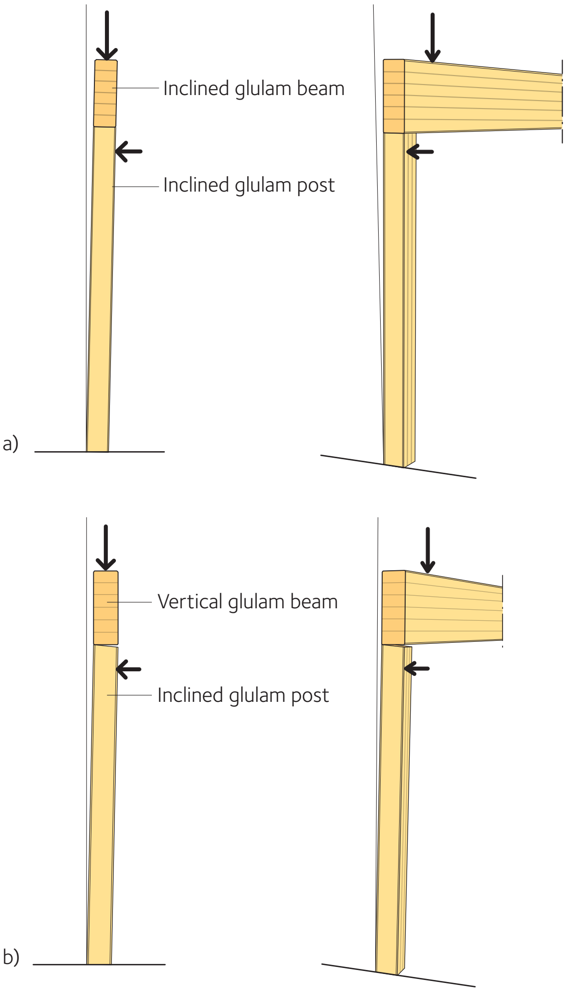


Figure 3.10 Skewed glulam structure
Self-weight, imposed load and snow load cause an undesirable horizontal load in the glulam structure.
a) Example of inclined glulam post and beam.
b) Example of inclined glulam post and vertical glulam beam.

3.4 Site tolerances for glulam frames – requirements

Tolerances when installing glulam should meet the requirements specified in the current Swedish construction industry standard for house-building, AMA Hus. According to AMA Hus, building site tolerances are the final requirement after the tolerance requirements for manufacturing, setting out and installation have been weighed together. RA Hus contains advice and instructions on drawing up an assembly plan or description.

It is important to insist that the groundwork contractor maintains the tolerances for the foundations and that they are measured before assembly of a glulam frame can begin. Glulam elements are very precisely manufactured and maintain their manufacturing tolerances well. Fittings used to join glulam elements are often simple, but they cannot generally be used to correct errors caused by poorly made connections.

When installing glulam, it is important to minimise misalignment, as this causes unwanted permanent loads in the structure. It is therefore important to ensure that glulam posts and beams are installed according to the drawing. Glulam posts should be vertical and glulam beams should not incline sideways, unless otherwise specified.

If the developer wants tighter tolerance requirements than AMA Hus, the project planner can include this in the documents for the specific project. It is recommended that the tolerances are continuously checked throughout the assembly phase and that the foundations and the placement of castings are carried out with an accuracy that matches what the glulam frame requires.

Castings and supports must be measured and deviations in position, level and flatness recorded. Deviations greater than the approved tolerances must be remedied before the glulam installation begins. The final survey report must be submitted to the contractor performing the glulam installation.

The position, straightness and plumbness of glulam elements should be checked during installation using a laser instrument, total station or theodolite. A good spirit level may be sufficient for smaller buildings.

To make it easier to bring the glulam assembly within the parameters of the given dimensional tolerances, it can be a good idea to start the assembly of the glulam frame where the permanent stabilisation will be. Installing the permanent wind braces or struts at an early stage establishes a better starting point for subsequent assembly.

Each truss line must be braced separately by fitting compression struts against the first stabilised line in order to obtain the correct position and straightness.

Glulam purchasing and procurement of glulam installation

4.1 Building contractor's glulam purchasing options

Since there are many variables when procuring glulam for a building, the buyer needs to check what is appropriate for the specific project. The options differ in terms of the level of finishing work required on site.

Here are a few examples:

- If only glulam dimensions and quantities are specified, the purchase may comprise glulam in straight cut lengths, as approved by the client. The building contractor will then have to produce final length measurements and finish the glulam elements on site. This is a common level for small-scale construction projects.
- If the project planner has drawn up structural drawings for the glulam elements but has not made any production drawings for them, the purchase may include the glulam manufacturer drawing up production drawings and offering a finishing service.

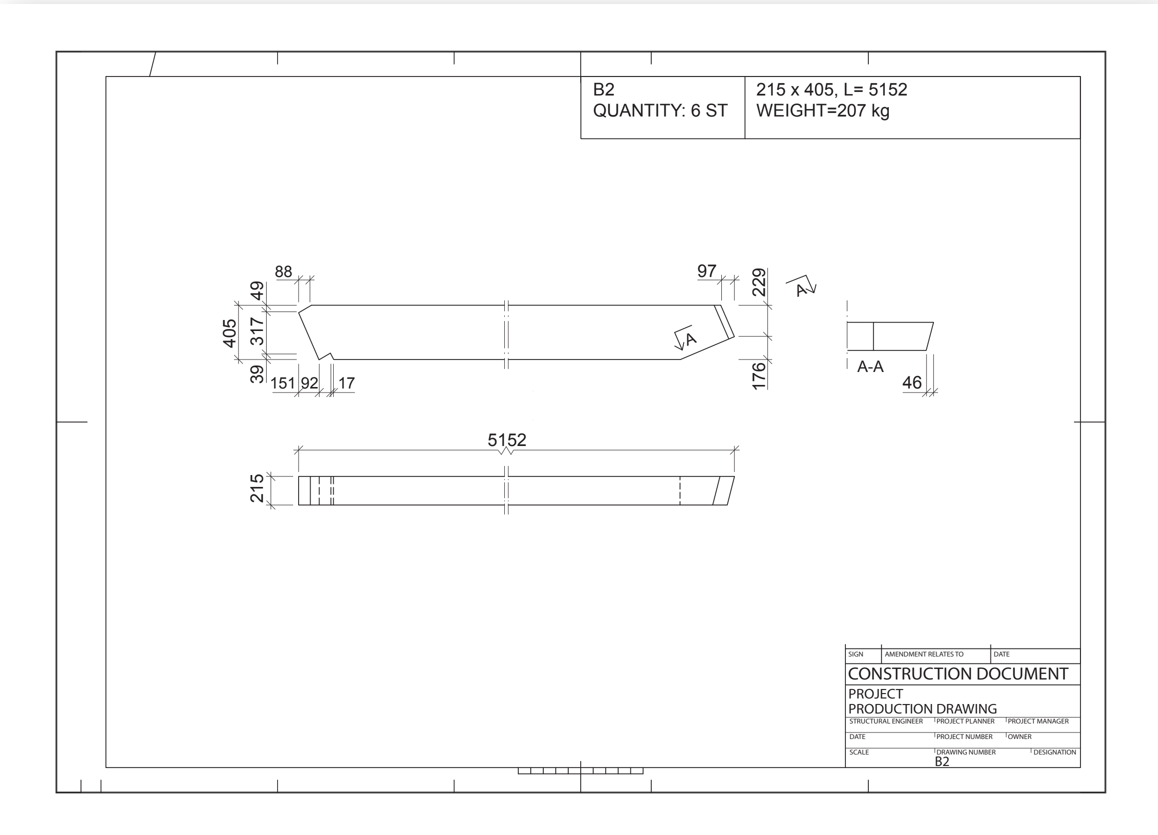


Figure 4.1 Example of a production drawing for the finishing of a glulam beam

CNC machine at a glulam manufacturer.

This requires a little extra time as there are often questions about particular dimensions or details and the buyer needs to review the drawings and approve them.

- The project planner has prepared production drawings for each glulam element to form the basis for processing at the glulam manufacturer. Some glulam elements are processed manually from the production drawings, while other production drawings are converted into digital control documents for the CNC (Computer Numerical Control) machine that the glulam manufacturer will use to carry out the work. This option results in a finished kit excluding the required fittings.
- If the glulam frame is not fully designed by the client, the glulam manufacturer can offer to perform this function, submitting a tender for both design and delivery. The appearance of the documentation is of little importance as long as it reflects the client's requirements. With this option, the purchase includes both design and delivery of the glulam and its associated fittings. The extent of this work depends on the complexity of the building. Halls are often simple with few utilities, so this is an example of a building type that is well suited to this procurement option.

AB 04
The General Conditions of Contract for Building and Civil Engineering Works and Building Services are intended to be used for pure construction contracts, where the client provides the design.

ABT 06
The General Conditions of Contract for Design and Construct Contracts for Building, Civil Engineering and Installation Works are intended to be used for contracts where, in addition to the actual construction, the contractor also has to produce all or a substantial part of the design.

4.2 Procurement of glulam installation

Glulam manufacturers are able to offer installation of their products. Rather than having their own team of installers, they will usually have contractors with whom they cooperate and who have extensive experience of installing glulam frames.

It is also possible to procure the glulam installation directly from a contractor without involving the glulam manufacturer.

A good quote requires documentation that allows the installation contractor to calculate the installation time, manpower and equipment requirements:

- Plan and section drawings.
- Quantity of constituent building elements.
- Draft assembly plan by the chief structural engineer.
- Preliminary site layout plan showing available space and crane routes. See example in *figure 5.1, page 27*.
- Provisional timetable and details on number of mobilisation activities.

Glulam installation is a type of building contract, and as such it is covered by the General Conditions of Contract for Building, Civil Engineering and Installation Works, AB 04 or ABT 06. These set out the contractual conditions that apply to the work, usually AB-U or ABT-U, as it tends to be a subcontract supplemented with special provisions that are specific to the glulam contract in question.

Planning glulam installation

5.1 Site layout plan for glulam frame assembly

It is important to consider the size and characteristics of the glulam elements in an up-to-date site layout plan, to make sure there are places to put the material after unloading.

The site layout plan should ensure that the glulam elements can be laid out without any risk of being damaged by other activities on site. The glulam elements should, of course, also not pose a danger to any other on-site activities.

The size of the storage area available depends on the type of construction site, but it is necessary to provide places where unloading and further handling can take place safely. It is important to consider all this early in the planning process, otherwise a situation may arise where other materials have to be moved urgently to accommodate the glulam elements. *See figure 5.1*.

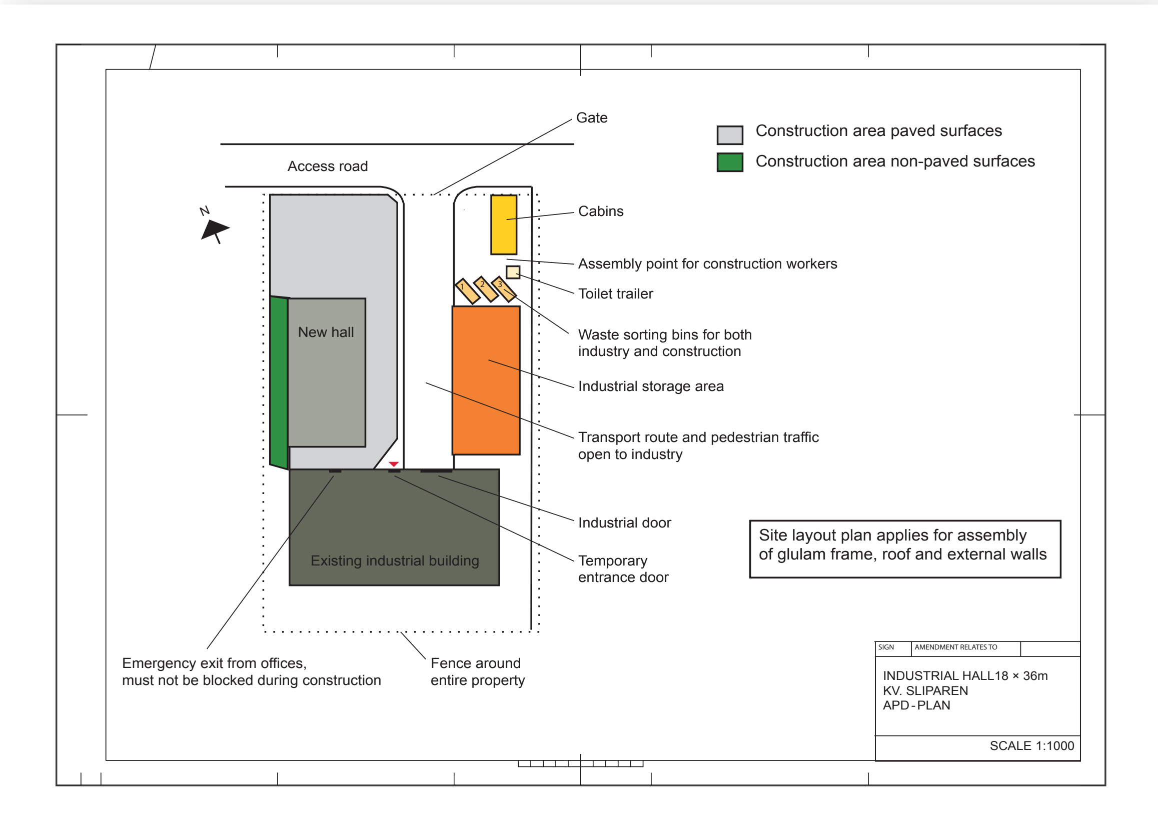


Figure 5.1 Example of a site layout plan

Lifting glulam elements with a mobile crane.

Assembling a storage structure using a truck-mounted crane. Posts and roof beams in glulam, with floor and stairwell in prefabricated concrete.

When building halls, there are often large areas that can be used for material handling, making accessibility and the size of the crane important factors. Large spans mean larger and heavier glulam elements, thus requiring larger cranes.

If the construction site only has small areas available for storage of glulam elements, you may have to divide the consignments into several smaller deliveries. This will increase the transport costs and the environmental impact, but may be the best solution in terms of both overall economics and the working environment. Stacking too much material can cause damage and requires extra time to move the material.

The efficient and safe assembly of a glulam frame requires good ground conditions for the movement of cranes, lifts and other heavy traffic. Unevenness and piles of gravel are both problematic and dangerous in areas earmarked for the unloading, storage and handling of glulam elements.

Areas where the ground does not meet the load-bearing requirements should be marked both on the site layout plan and in real life, to avoid accidents.

It is advisable to clear the site layout plan with all concerned, particularly the personnel who will be installing the glulam frame. There is often just one subcontractor who is responsible for assembling the glulam frame, and it is crucial that they are given a say in the site layout plan.

The plan is a document that may change from day to day as construction progresses and it needs to be able to cope well with large deliveries. A carefully considered site layout plan helps with coordinating incoming goods and making sure that deliveries can be spread out over time, rather than all turning up at once.

5.2 Assembly plan for glulam frame

According to the Swedish Work Environment Authority's rules, an assembly plan must be drawn up in good time and be approved by both the chief structural engineer and the person responsible for the glulam assembly.

If there is a site layout plan for the construction project, this should form the basis of the assembly plan covering the glulam installation.

If there is no established site layout plan, the assembly plan must also include information on storage areas, approved routes for cranes, lifts and other heavy traffic and the necessary barriers to prevent other personnel from entering the work area.

Structural and/or assembly drawings with marked installation order and markings for temporary bracing must be included in the assembly plan, along with the type and quantity of bracing material and how fixings are to be applied. There should also be a note on when the bracing material can be removed and what circumstances and requirements must be met before removal.

An assembly drawing with both line markings and colour markings is a good method, as it is clear even out on site.

The description should explain how the installation will be carried out, and what lifting techniques and machinery will be used. Depending on the experience of the installers, the scope of the description may vary, although it must always be tailored to the project in question. *See examples of assembly plans for glulam frames, page 62*.

It should also set out the necessary safety equipment relating to scaffolding, lifts and personal protection.

With glulam assembly, a lift or scaffolding should be used in the first instance. Personal protection such as a lifeline should be used as a last resort and only if installing a fixed safety device is highly complex and risky.

Before work can begin, the assembly plan must be reviewed with the installers and machine operators concerned. The assembly plan is to be drawn up in such a way that it can be easily understood by the personnel on the site.

Scissor lift and boom lift during assembly of glulam and CLT frame for school building.

5.3 Machinery for lifting glulam elements and access

The lifting of glulam elements and access for the installers are key factors in the assembly of glulam frames, so it is important to choose the right equipment for the project at hand — the right machine can improve both safety and installation time.

A crane is often the best option for installing glulam elements, due to its simplicity and precision. A tower crane or mobile crane can be considered equally valid choices.

However, when building halls, few of the lifts occur in the same place, which makes mobile cranes a better option. Mobile cranes are available in different designs and sizes, so you can choose the most suitable option for your project. Crane rental companies can usually help you choose an appropriate crane for the situation, both in terms of lifting capacity and access.

A rotating telescopic handler is a good machine if you can get close to the installation site, and glulam elements should be lifted with slings during assembly.

Fork or crane loaders can do some lifting, but they are not the safest or most efficient way of assembling glulam elements. They are, however, suitable for moving and unloading short glulam elements, especially if they are going to be finished on site.

A boom lift or scissor lift is the best way to raise people up to the level of the work, although in some cases, a crane basket may also be needed. If the surface is concrete or asphalt, scissor lifts work well and provide a large working surface to stand on.

Boom lifts also work well on concrete and asphalt surfaces, but they are better at off-roading than scissor lifts, so they also work well on gravel surfaces that have been impacted and levelled. A boom lift can also move faster, which is an advantage — often the time spent working on each connection from the lift is short.

Weather protection for glulam frame during construction

The time of year and the geographical location of the site determine what to focus on when handling and installing glulam. In autumn-winter-spring, it is important to ensure that the glulam is not soiled by rainwater or wet snow. Microbial growth, on the other hand, is something you usually don't have to worry about during the colder months.

Glulam that briefly becomes wet and is then placed under cover generally dries out to a moisture content that, as a rule, will not lead to microbial growth. Summer and early autumn, however, is the period when microbial growth can occur on glulam surfaces, so you must ensure a good air flow around the glulam elements. This applies during handling and storage as well as machining and assembly.

As a construction material, glulam is generally not adversely affected by rain, sunlight, heat or cold during the installation phase. The load-bearing capacity remains intact and the changes in shape that may occur due to rain or sun will rectify themselves once the glulam beams have regained their normal moisture content.

However, time and temperature are factors that must be taken into account, as the time for which the material is exposed to rain and sunlight is an important parameter for soiling and sun bleaching. If the glulam frame is to be painted after installation, exposure to rain and sunlight in the installation phase is not usually a problem.

A primer may be applied as an additional level of protection against microbial growth on glulam surfaces. There are special wood protection products that can prevent microbial growth, such as wood oil or a type of water-based, colourless wood primer.

Large glulam elements over 500 mm can develop small cracks when rapidly dried by sunlight — the surface heats up and dries, causing it to shrink a little, while the inner part retains its dimensions, creating tension in the glulam.

The following sections describe some different ways of providing weather protection, depending on the conditions and needs of the individual project.

6.1 Assembly of glulam frame without weather protection

Removing all packaging from the glulam elements before starting to erect the glulam frame is a common practice. It is not a good idea to mix glulam elements with and without packaging, as this will result in differences in appearance.

Exposing glulam elements to rain and snow does not usually cause major problems during installation. Since the elements often have relatively large cross-sections, it takes time for the moisture to penetrate — the surfaces may get wet but they will dry out quickly when the bad weather stops. However, end wood surfaces should be protected from precipitation. Time is a factor in the amount of water that penetrates the glulam — during normal exposure, the weather will alternate between damp and dry, so there is usually no direct moisture problem overall.

Sunlight dries and bleaches fully exposed glulam surfaces, while rain running along glulam elements carries dirt particles. When water is absorbed into the glulam surfaces, it can turn them slightly grey. This is normally not a problem if you get the roof on within a few weeks. The weather tends to vary between precipitation and sun, so the impact on the glulam will also vary.

As time is an important factor in avoiding the effects of weather on glulam, work on fitting the roof should be carried out immediately after assembling the frame. Getting a building frame under a roof quickly is extremely important, not only for the glulam but also for the rest of the construction work. Avoid leaving a glulam frame without a roof over holidays.

Coordinating with the roofing is perhaps the most important way of minimising the time that water has to affect the glulam. For glulam frames with an installation time of one to two weeks, the roof installation should ideally come directly after the glulam installation has been completed. With larger buildings, the installation should be divided into stages so that there is not too much time between the glulam installation and the building being roofed.

Daylight contains UV rays, so some bleaching continues when the building has a roof but no walls. However, the effect is much less than with direct sunlight.

If there are places where precipitation can run off along glulam surfaces after the roof is completed, these surfaces should be protected locally, for example at external walls, where it is sometimes not possible to manage precipitation from the roof in a controlled manner. Precipitation is usually contaminated with dirt that has accumulated on the roof and can result in unsightly stains on the glulam surfaces.

An assessment should be made before the first rainfall comes, to check whether anything needs to be done. It may be necessary to take action that prevents the water from running down the glulam posts. Cover the glulam post with a tarpaulin or similar protection if the water cannot be channelled away.

Glulam beams and posts that are exposed in the finished building usually have no problems with microbial growth, as the surface moisture content of glulam adapts fairly quickly to the level that is outdoors under a roof, i.e. 16 — 18 %. Once the building is completed and heated, the relative humidity (RH) in the indoor air falls below 60 % and then the glulam eventually adopts the equilibrium moisture content of 10 — 12 %. For microbial growth to occur, the surface moisture content must be higher than 20 % for a prolonged period of time.

Note that glulam surfaces should be checked during installation. If water marks are found on the glulam, the surface should be wiped as soon as possible with a damp cloth and a little added detergent.

Assembling the glulam frame in the summer months without weather protection.

Assembling the glulam frame in the winter months without weather protection.

Assembling the glulam frame with original packaging as weather protection.

Assembling a timber frame in a dense urban environment. Temporary market hall.

6.2 Installation of glulam frame with original packaging as weather protection

Large glulam elements and glulam elements purchased from timber and builders' merchants are usually wrapped individually in recyclable material and can be assembled with the packaging on. Checking the appearance of and any apparent damage to the packaging determines whether it is necessary to investigate any potential damage to the glulam element. This must be done before the glulam element is built into the structure.

If moisture forms inside the packaging, it should be cut open at the bottom, preferably repeatedly at a spacing of around 0.5 – 1 m, to remove any condensation and allow the glulam element to dry out. In case of doubt, consider removing the packaging completely.

The packaging may need to be opened for the elements to be arranged in storage and for some kinds of hardware to be attached. However, it is difficult to reseal the packaging in a way that protects it from precipitation.

Keeping the packaging on during installation will usually deliver a good end result, but the wrapping needs to be removed before the roof is installed – otherwise cutting it away will be hard work.

In the case of load-bearing metal roofing sheets, the packaging can be cut away when the first roofing sheets are laid. The risk here is that if some parts have packaging and others do not, the weathering effect on the glulam frame will vary, particularly in terms of uneven fading.

6.3 Assembly of glulam frame with surface treatment as weather protection

A surface treatment can provide good protection against soiling and to some extent against fading, depending on the products used.

A transparent lacquer provides a surface that does not absorb water in the same way as an untreated surface and therefore stays cleaner than an untreated surface. Some fading will still occur as the lacquer does not completely block UV rays. The treatment is also resistant to mechanical impacts and damage rarely occurs during normal handling. Clear coatings containing UV filters are also available.

Glulam manufacturers can offer surface treatment of their glulam products, except for the stock range which is always delivered untreated.

Wood stains do not soak into the relatively hard planed surface of glulam elements. They provide some resistance to the solar effects that may occur during assembly, but their durability is limited to 3 – 5 years of outdoor exposure.

Most types of film-forming coatings provide good protection. The glulam manufacturers offer suitable systems that work best with their production, both practically and environmentally.

See also *Surface treatment of glulam, page 59*.

6.4 Assembly of glulam frame with partial weather protection

If certain parts of a building are subject to high standards of surface finish after installation, a local covering over individual glulam elements may be necessary. To prevent water running along glulam beams and posts, they must be protected from above with some type of waterproof material, while glulam posts that are exposed to water from the sides can be covered with a windproof and water-repellent material. Using an opaque material makes it more difficult to see if something is happening under the cover, but on the other hand it provides better protection against UV radiation.

Assembling the glulam frame for a multi-storey building without weather protection.

6.5 Assembly of glulam frame with cover, temporary shelter

Constructing an entire building under a shelter that provides protection from both rain and sunlight is very useful, but often prohibitively expensive when constructing ordinary buildings.

Scaffolding with façade protection around the building is a good option if required for the construction of the walls. Otherwise, it is expensive compared to planning the installation up to the point at which the roof is in place.

Where there are large quantities of installations and other moisture-sensitive materials that need to be fitted or used before the final roof can be completed, a local shelter may be appropriate, but generally speaking, glulam frames do not need to be built under shelters.

Temporary shelter to protect against the weather when building a timber-framed apartment block.

6.6 Temporary weather protection to remain in place

Agree at the start of installation on the type of weather protection to be used and whether any part of the protection will remain in place for further construction after the glulam installation is completed. It should be clearly stated who will dismantle the weather protection after it is no longer needed. The glulam installers are usually not present when any remaining weather protection is removed. Make an extra check with the site manager as part of the inspection of the glulam installation.

6.7 Important advice to avoid discolouration of glulam elements

When installing glulam frames that will remain visible without any additional paint treatment, extra care must be taken to ensure that the glulam surfaces are not soiled by handling or precipitation and are not exposed to sunlight.

Assembly of three-hinged roof trusses in glulam with steel ties on glulam posts.

Here are a few key points to help you achieve a good end result:

- Avoid fittings or other materials above or on the outside of the glulam that might release dirty water to soil the glulam.
  - Steel fittings of all types often become oily after manufacturing and galvanising, so it is a good idea to wipe them off before installing them on the glulam elements. An installer may be wearing oily gloves that could contaminate the glulam surfaces.
  - Water from nearby buildings should be diverted.

- Load-bearing sheet metal roofing is good because it quickly provides a protective roof over the glulam. **Note** that water from sheet metal roofing can discolour glulam if it drains onto glulam roof beams and posts. Here is some important advice:
  - The load-bearing roofing should be installed so that the lower sheet extends beyond the glulam roof beam by approximately 300 mm, ensuring that water from the roof can drain past the glulam beam, *see figure 6.1*.
  - The sides of glulam gable posts might be exposed to water running off the metal roof and should therefore be protected.

The following actions should be performed daily:

- Check if water is flowing in any area and consider whether any action is needed. It is usually easy to see why water is running in a particular place. Any water should be channelled away.
- Wipe wet and dirty glulam surfaces with a damp cloth and a little detergent.
- Also make sure that glulam posts are not standing in water that exceeds the level of the moisture protection on the foot of the post.
- Check that dirt cannot be splashed onto the glulam posts.

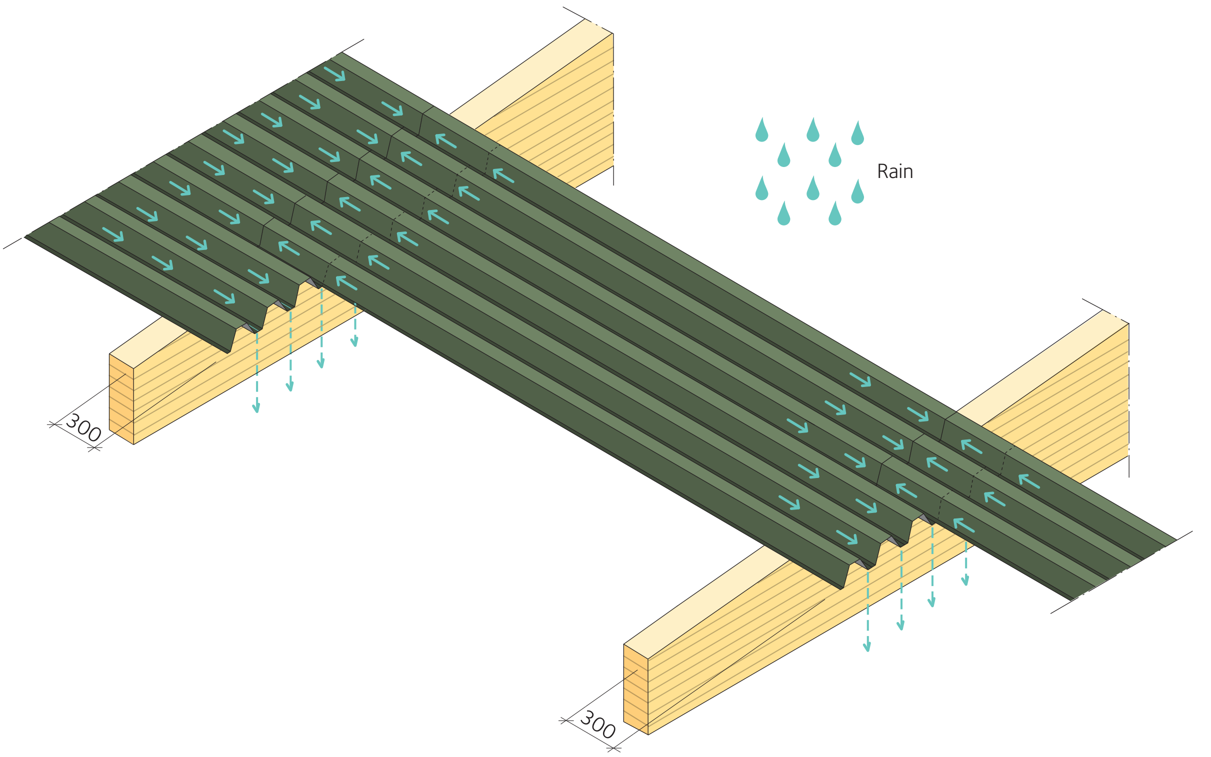


Figure 6.1 **The corrugated roofing is installed so that the lower sheet overlaps the glulam roof beam by 300 mm to prevent water from discolouring the beam**

On-site glulam modifications

7.1 Planning modifications to glulam elements

If the final machining of the glulam elements is not carried out by the glulam manufacturer, a place to carry out this work must be set up on the construction site.

Small glulam elements can be modified with a fixed mitre saw, while the larger ones require hand-held machines, as the glulam elements can be unwieldy to move around.

It is important to ensure that the glulam elements are stable and that they are anchored to prevent sliding. Glulam elements weighing a few hundred kilograms are impossible to move easily by hand, and require lifting aids. A loader or telescopic loader often works well here, but if you have access to a crane, even better.

From an ergonomic point of view, efforts should be made to position the glulam elements at a good working height. It is important from a safety point of view to stand securely when working with hand-held cutting tools.

Trestles should be set up as a base for further processing of the glulam element, preferably 400—800 mm above the ground or floor, *see figure 7.1, page 36*. This also facilitates preparation for fittings that will be placed on the underside of the glulam element. The trestles are to be positioned so that there is no risk of sawing into them during the machining.

When working with glulam, it is important that support surfaces are always flat to ensure good contact between the glulam element and the supports. This applies in particular to contact surfaces between glulam primary beams and glulam posts, where the loads are often high. A poor fit quickly gives rise to misalignment and unwanted loads and deformations.

Obtaining flat glulam surfaces for joints requires good machines, especially if a large number of glulam elements are to be worked on. Modern chain beam saws and circular saws with guide rails can handle most types of work.

While an experienced carpenter or installer can achieve a good result using common hand tools, it is difficult to achieve consistent quality when many glulam elements are involved, and time is often short.

Transporting a long glulam beam with a telehandler on the construction site.

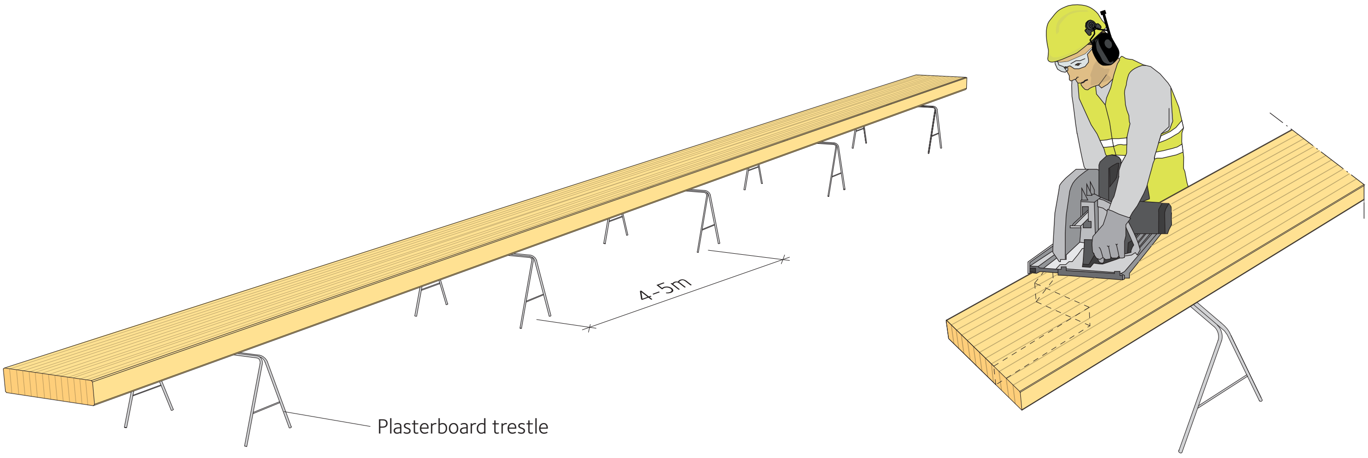


Figure 7.1 **Plasterboard trestles can be used for machining glulam elements on site**

7.2 Space requirements and placement of glulam elements

The space needed for machining on site is determined by the length of the glulam elements and the handling method chosen. Glulam elements with a length of up to 10–12 m are easy to handle in terms of both weight and length and work well on a construction site. Longer and larger glulam elements that are not finished by the glulam manufacturer should be laid out where they will be installed to avoid having to move them after modification – perhaps they can be laid there straight from the delivery truck. Plasterboard trestles or pallets are possible alternatives to traditional wooden trestles and are less expensive. It is also beneficial if the glulam elements can be set up some distance from the ground.

7.3 Machinery requirements for lifting and modifying glulam

If a central location is going to be set up for the modification of glulam elements on site, it is advisable to arrange or design the workplace so that the glulam elements can be handled by a loader or a telehandler. After finishing, the glulam elements can be lifted to a prepared location from which they can then be moved to the right location in the building or lifted directly into their final position.

In addition to the lifting machinery, good woodworking tools are required, and it is worth having a cutting station for cutting short glulam elements to length.

Good hand-held tools are usually the best choice for working on glulam elements on site. Circular saws and chain beam saws with guide rails for straight cuts help to ensure the right quality of cut surfaces. Circular saws can generally handle glulam elements up to a thickness of around 120 mm. Larger thicknesses require a chain beam saw, which can handle glulam elements up to 300 mm thick.

Ordinary chainsaws do work, but they make it more difficult to achieve the necessary precision, not least on load-bearing surfaces.

Drills and jigsaws are other examples of the hand tools needed, and possibly a router to make recesses for fittings. Screwdrivers with sufficient torque are necessary when working with long wood screws, while a handsaw, chisel and handplane also make the job easier.

Examples of common power tools and hand tools for modifying glulam.

7.4 Holes and notches in glulam, plus reinforcement

Holes and notches in glulam elements must be shown on the structural drawing, as checked by the chief structural engineer, who must also specify any reinforcements.

Notches should generally be avoided in glulam beams, but some need to be made for the element to function as a building component.

Figure 7.2 shows a schematic diagram of how a glulam roof beam can be modified to provide good alignment without adversely affecting the structure.

All glulam beams that are on a slope, such as roof beams, are usually constructed with horizontal support points for the glulam posts and walls, and it is here that certain basic interventions can be made in the glulam element without significantly weakening it.

In general, holes with a maximum diameter of 50 mm can be made almost anywhere on a glulam beam, but not in the three outermost lamellas, i.e. within the range of 135 mm from the lower and upper edges, nor near support points. Small holes should be spaced at least 150 mm apart. Larger holes or more than five holes in a row must be approved by the chief structural engineer.

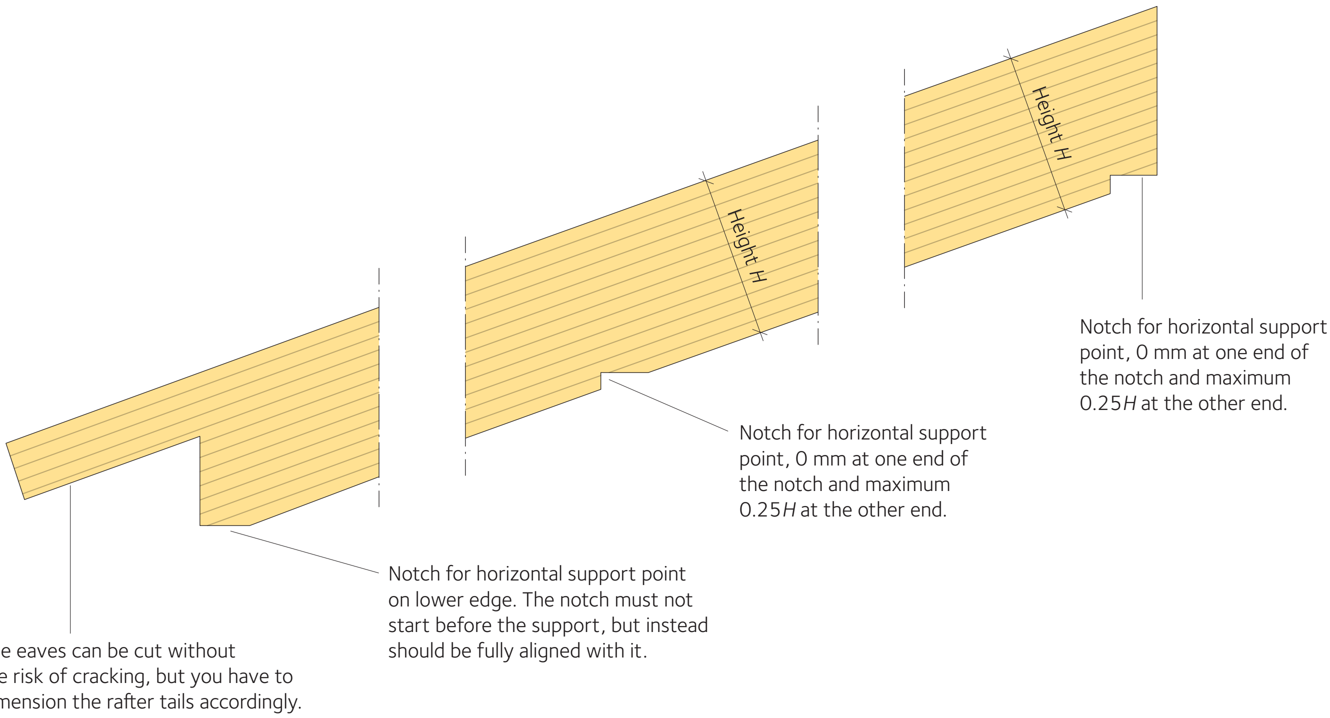


Figure 7.2 **Example of a glulam roof beam modified on site**

Notches without reinforcement are best made with a rounded inner corner.

Larger notches often require reinforcement. Example of notch with rounded corner and screw reinforcement.

Example of notch and reinforcement with structural plywood that is screwed and glued to the glulam beam on both sides.

When sawing notches, it is important not to saw too far as this will create the potential for splitting. One tip is to drill with a 25—30 mm drill bit in the inner corner before you start sawing. This makes it easier to see where the sawblade is and provides a good notch with a rounded inner corner.

Holes are best made with a wood drill or hole saw.

Holes and notches other than those mentioned above often require some form of reinforcement, which must be approved by the chief structural engineer.

The middle picture shows the principle of how a notch in a glulam beam end can be strengthened with a long, fully threaded wood screw or universal screw, which reinforces the glulam beam. Wood screws are described in more detail in the next chapter *Installation of glulam fittings and fixings, page 39*.

Note that only minor notches may be made without the approval of the chief structural engineer, who must provide instructions for holes and notches and, if necessary, prescribe appropriate reinforcement.

Installation of glulam fittings and fixings

There are many different methods of connecting glulam elements to each other and the chief structural engineer or architect is usually the one chooses the type of fittings based on strength and appearance.

A wide range of standard metal fittings are available for joining glulam, and they can be ideal for smaller glulam structures.

Larger structures usually require custom fittings, which are shown on the structural drawings for each individual project.

The durability and intended service life of the joint types are to be adapted to the relevant corrosivity class, which is determined by the project's surrounding environment. Indoor environments and unheated spaces correspond to corrosivity classes C1 – C2.

Most standard steel fittings are hot-dip galvanised with corrosion protection Z275 according to SS-EN 10346, which gives a surface layer thickness of ≥ 20 µm (micrometres). This corresponds to the requirements for climate class 2 in Boverket's building regulations (EKS), and roughly equates to corrosivity class C2 as set out in SS-EN 14592. Although there is currently no correlation between climate classes and corrosivity classes, these fittings can generally also be used in structures in climate class 3, as they are often protected from direct exposure or painted with corrosion protection on site after installation.

Steel plate fittings to be used outdoors with direct exposure, such as post shoes, should be hot-dip galvanised with corrosion protection Z350 for corrosivity class C4 or have a special coating for corrosivity classes C3 – C4 with documentation of durability and expected lifetime from an accredited certification body.

Corrosion protection Z350, which corresponds to a layer thickness of ≥ 50µm, is expected to provide durability of at least 20 years. The chief structural engineer selects the required corrosion protection for the individual project, in consultation with the client.

In the event of particularly high demands for the durability of corrosion protection, fittings made of austenitic stainless steel A2 for corrosivity class C4 or austenitic stainless steel A4 for corrosivity class C5 should be used.

Fasteners for relevant fittings must have at least the same corrosivity class as the fitting. In some cases, for example if pressure treated glulam is used, fasteners should have a higher corrosivity class than the fitting, *see also section 8.1, page 40*.

It tends to be the chief structural engineer who specifies the quality, dimensions, design, execution and corrosivity class of all the different types of steel fittings, with the details for each individual project provided in the design documents.

Manufacturers of structural hardware usually have detailed information and instructions on the use and design of their products.

Glulam post-beam connection with UPE steel U-channels and fastening with machine-threaded screws and nuts.

This section describes how to work with certain steel fittings in glulam assembly:

- Standard metalwork fittings for small glulam structures: nail plates, hangers and angle brackets.
- Anchoring of glulam posts to the foundation: hinged posts and fixed posts.
- Fixing between glulam post and beam with nail plates.
- Fixing between glulam post and beam with cover plates.
- Fixing between primary and secondary glulam beams with wood screw joints.

8.1 Fasteners for steel fittings in glulam structures

Metalwork fittings are provided with a number of holes for nails or wood screws. These fittings use a type of anchor nail known as an annular ringshank nail, or a type of wood screw known as an anchor screw, which have a higher pull-out strength than conventional nails or wood screws, plus a head adapted to the holes in the fitting.

Anchor nails are available in strips for nail guns, which speeds up installation as a large number of anchor nails can quickly be inserted into these joints.

You should use a nail gun that is designed for anchor nails and nail into the holes in the fitting. One type of nail gun that works well is a pneumatic nailer with a magazine for coiled anchor nails. These machines have their own compressor and an approximately 30 m long hose wound on a reel.

Anchor screws are usually installed using a screwdriver – although strips of anchor screws are also available for auto-feed screwdrivers.

The type and number of fasteners to be used is specified by the chief structural engineer on the structural drawings, which should also include information on the strength class and lengths of nails and wood screws.

Fasteners are matched in terms of durability and life expectancy to the relevant corrosivity class. The corrosivity class of the fasteners should generally correspond to the corrosivity class of the steel fittings, and this information should also feature in the structural drawings.

UPE profile, flat steel or glulam cover plates are employed on larger structures and often use machine-threaded coach bolts with washers and nuts. Glulam plates can be designed to meet fire safety class R30 or R60.

There are several types of wood screws that can be used for mounting steel fittings on glulam. The type known as the French wood screw requires pre-drilling. The shaft of a traditional French wood screw has an unthreaded part of the same diameter as the threaded part, which can lead to cracking if the diameter of the pre-drilled hole is less than or equal to the diameter of the unthreaded part. The traditional model of the French wood screw has now been superseded by more modern options, such as the hexagonal wood screw.

Modern wood screws are self-drilling and generally do not require pre-drilling. A special double-threaded screw – universal screw – can be used as a connector without fittings.

The structural drawings must specify how any fittings and fasteners are to be installed.

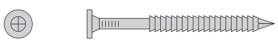


Figure 8.1 **Anchor nail**
Used in combination with metal plates.

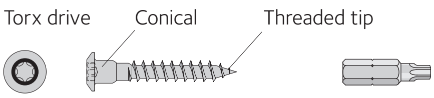


Figure 8.2 **Anchor screw**
Used in combination with metal plates.

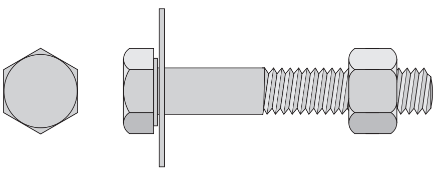


Figure 8.3 **Coach bolt with washer and nut**

The hexagonal wood screw is designed to attach heavy steel fittings to large glulam structures and is available in a wide range of dimensions and lengths. This is the part of the neck directly below the head that will fit into the hole in the fitting. It is important to choose the right hexagonal wood screw for the fittings in order to achieve a strong joint.

Hexagonal wood screws with a torx head are made of hardened steel and are self-drilling, making them an excellent replacement for the French wood screw. The hexagonal wood screw is robust and is available with varying thicknesses of zinc coating, depending on the desired service life. This type of wood screw is easily driven into the glulam, prevents cracking and can be used with square or round hot-dip galvanized steel washers.

Advanced glulam structures often use steel dowels with steel plates inset into the glulam elements. Instructions for this, including pre-drilling, should feature in the structural drawing.

Self-drilling dowels may also be combined with inset steel plates, and in this case the dowel manufacturer should be contacted for the necessary instructions on installation.

It tends to be the chief structural engineer who specifies the type of fastener, the quality and the corrosivity class, with all this information shown in the structural drawings. Manufacturers of nails and wood screws usually have detailed information and instructions on use and dimensioning.

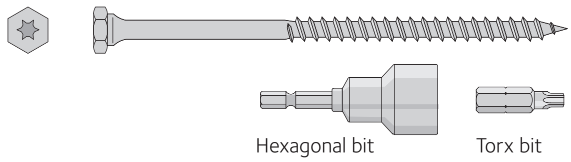


Figure 8.4 Hexagonal wood screw. With specially designed threads. No need for pre-drilling.

Figure 8.5 Dowel. Used to assemble inset steel plates in wooden structures.

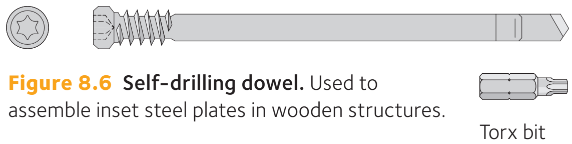


Figure 8.6 Self-drilling dowel. Used to assemble inset steel plates in wooden structures.

8.2 Correct installation of steel fittings for glulam structures

Common fittings such as nail plates, hangers or angle brackets may in some cases be considered aesthetically acceptable, provided they are installed in a neat manner in terms of orientation and fit.

From an aesthetic point of view, it is important to ensure that the fittings are placed so that they do not deviate from the plumb line or vary in height, etc. Measuring by eye may be sufficient, but there is nothing wrong with checking measurements or using a spirit level.

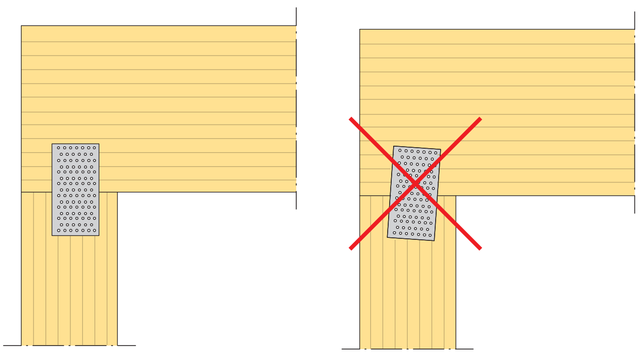


Figure 8.7 Nail plate at glulam post-beam connection. Fittings should be installed vertically. The figure on the right shows what careless installation can look like.

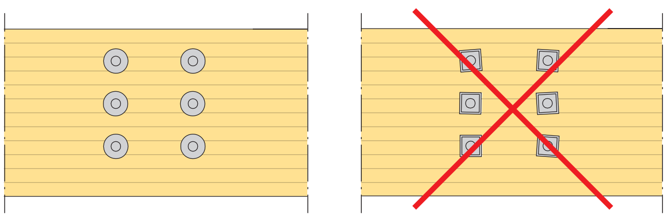


Figure 8.8 It is preferable to choose round washers. The figure on the right shows how untidy square tiles can look.

It is important to comply with the minimum edge distance for fasteners, especially the distance from the end wood. These spacing requirements vary depending on the directions of force in the joint. The examples of common joints below clearly show how normal connections work. If in any doubt, contact the chief structural engineer to obtain the correct information.

The most common standard metal fittings are made from 1.5 – 3 mm sheet metal that is cut, punched and bent to shape. The holes are 5 mm in diameter and designed for anchor nails or anchor screws. No other type of nail or screw is permitted, as it would significantly reduce the load-bearing capacity of the fittings.

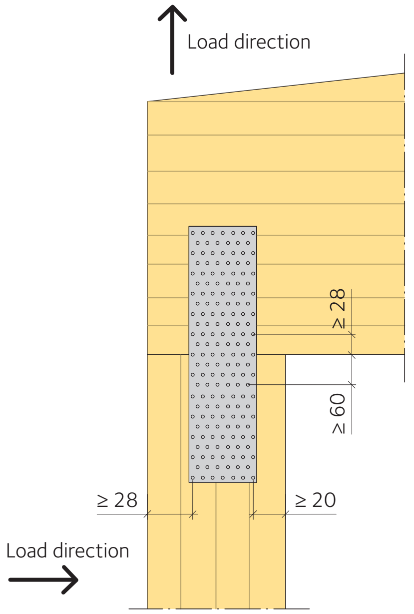


Figure 8.9 **Minimum edge distance in glulam for 4 mm diameter anchor nails according to Eurocode 5**

8.2.1 Edge distance for anchor nails and anchor screws

With every kind of joint and material, it is important to install the fasteners at a safe distance from the edge to avoid cracking and breakage.

Wooden structures require different edge distances, depending on the position of the fixing and the nature of the loads on the wooden element. The regulations are not entirely definitive, but in general the following applies:

- In the case of end wood, when the fitting is subject to tensile stresses, apply a distance from the end of at least 15 times the diameter of the nail, 15*d*.
- Perpendicular to the grain, a distance from the unloaded edge of at least 5 times the diameter, 5*d*, is required. For the loaded edge, the distance is 7 times the diameter, 7*d*.

An example of the minimum edge distance for glulam and 4 mm diameter anchor nails is shown in *figure 8.9*.

These minimum edge distance requirements apply to many types of fasteners and fittings. It can sometimes be difficult to describe the direct action of different forces, so it is important that the requirements are adhered to and the structural drawings are carefully followed.

Advice on fixings is given in this chapter alongside a description of some common types of fittings.

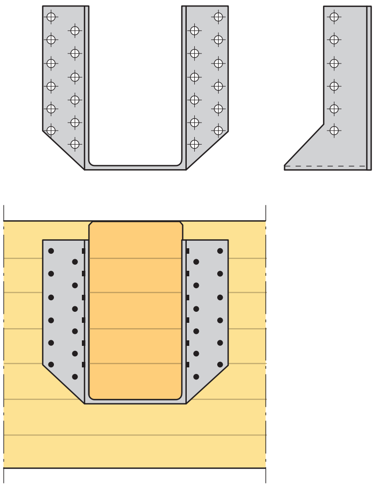


Figure 8.10 **Example of a hanger with external fixing flanges**

8.2.2 Fitting steel hangers for glulam structures

The installation and assembly procedures for the different types of hangers are basically the same as for nail plates.

Here we describe the principle for fastening a secondary glulam beam to a primary one. Mark on the primary beam or glulam post where the secondary beam is to be connected to ensure that the hanger ends up in the right place, at the right level and at the correct angle. Also ensure that the opening at the top of the hanger is large enough to take the glulam beam.

This operation requires great accuracy – carelessness leads to poor quality and a longer installation time. Use a set square and spirit level.

The function of the bottom plate in a hanger is to facilitate further assembly, while the fasteners transfer the load from beam to beam or post. It is therefore important to ensure good contact between the glulam beams by precision cutting the beam before it is inserted into the hanger.

Hangers with external flanges are attached by one flange to the primary beam. The second flange is initially attached only at the bottom. The next step is to install the secondary beam, after which the second flange is finally attached to the primary beam. This procedure provides a tighter connection between the hanger and the secondary beam.

Hangers with internal flanges must be fully attached to the primary beam or glulam post before the secondary beam is installed. As such, extra care must be taken to fit the hanger so that the flanges connect to the secondary beam correctly. It will not be possible to change the position of the hanger on the primary beam or glulam post at a later stage without dismantling the secondary beam. Consequently, using a hanger with internal flanges requires extra care, but gives a cleaner appearance.

Note that a hanger with internal flanges has a face thickness of around 7 mm – 3 mm steel plate + 4 mm anchor nail head – which means that the secondary beam must be 7 mm shorter compared with a secondary beam installed in a hanger with external flanges.

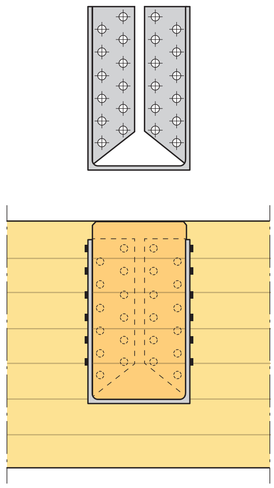


Figure 8.11 Example of a hanger with internal flanges

8.2.3 Fitting steel angle brackets for glulam structures

Angle brackets for timber joists or glulam purlins are available in many sizes and designs. *Figure 8.13* shows double angle brackets placed on a glulam post for fixing a horizontal timber joist.

The nailing pattern can vary depending on the application of the bracket, with the required number of anchor nails or anchor screws depending on the load the bracket has to withstand.

Figure 8.12 shows the difference between minimum and maximum nailing or screwing for one of the most common angle brackets with a width of 105 mm. Dimensions and load-bearing capacity vary between different hardware manufacturers.

The minimum distance between the fastener and the glulam edge or end must of course be taken into account when using angle brackets.

The fitting manufacturers' product information will contain detailed advice, and they are also able to provide sound guidance on selecting angle brackets for different situations and load conditions.

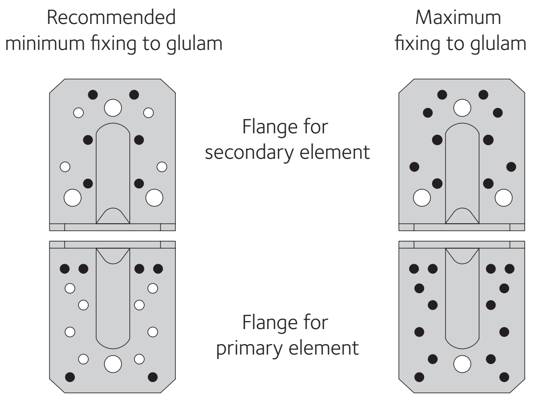


Figure 8.12 Joining primary and secondary glulam elements with angle brackets. Example of minimum and maximum nail or screw pattern for a standard angle bracket.

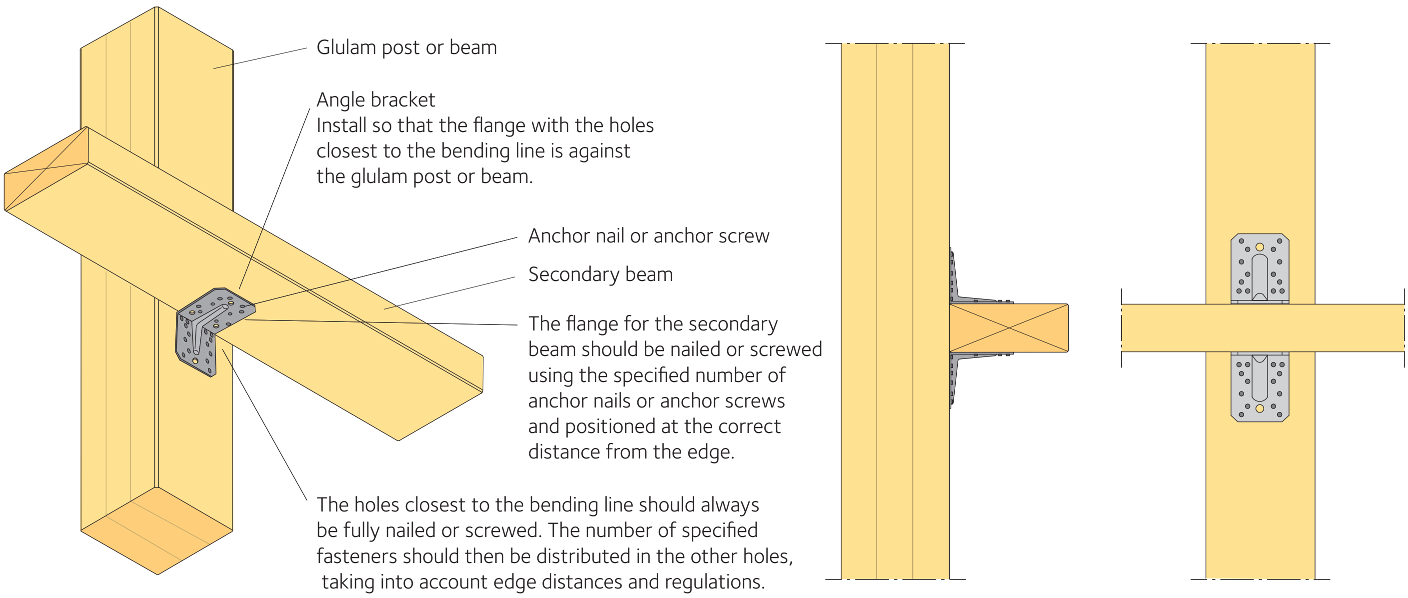


Figure 8.13 Assembling joints with double angle brackets

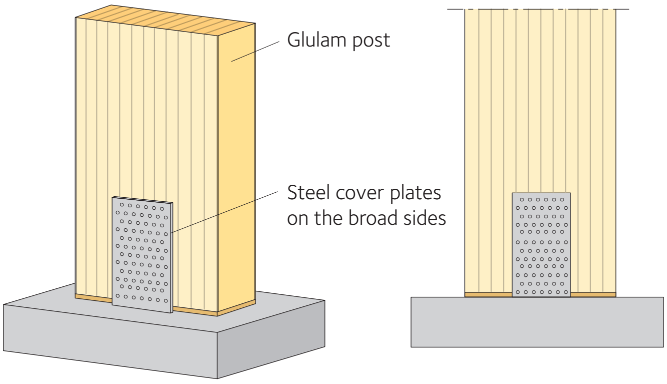


Figure 8.14 Steel cover plates at base of glulam hinged post

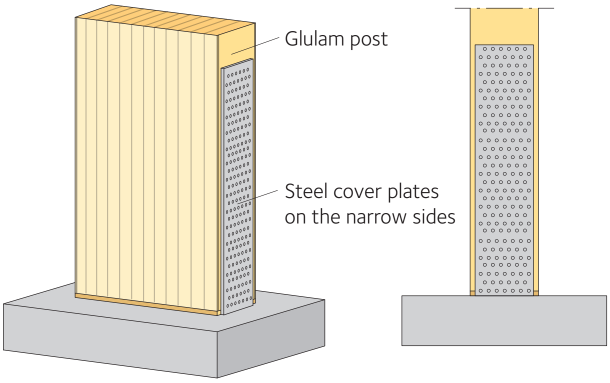


Figure 8.15 Steel cover plates at base of fixed glulam post

8.2.4 Anchoring hinged posts to the foundations

The glulam post is placed directly against a concrete slab or footing that usually has cast-in fittings to fix the glulam post in place and anchor it against the loads to which it may be subjected. Downward vertical loads are taken care of by direct contact with the ground, while horizontal and upward loads are taken up by the fitting in the foundations. Here the fasteners transfer the load from the glulam post to the fitting.

Usually the fittings are nail plates either cast into the foundation or designed to be welded to a steel plate cast into the foundation.

The welding option is the simplest way to get the fitting in the right place, as marking the position of the fittings is easy once the castings are done. However, there is no chance of lateral adjustment of the glulam post after the fitting has been installed.

The fasteners can be anchor nails, anchor screws or hexagonal wood screws, depending on the choice of the chief structural engineer. Start with the fasteners at the outer edges of the fittings and then fill in towards the centre.

8.2.5 Anchoring fixed posts to the foundations

The principle for installing a fixed glulam post is the same as for a hinged post, but the fittings have changed position and are instead located on the narrow sides of the glulam post. Once again, it is vital that the fittings are correctly positioned as there is no possibility of subsequent adjustment.

8.2.6 Fixing glulam posts to glulam beams with nail plates

- Mark where on the glulam post the nail plate should be located according to the structural drawing. Mark on the nail plate in which holes the nearest anchor nails are to be inserted to obtain the correct distance from the edges and the top of the glulam post. This procedure also applies to the glulam beam.

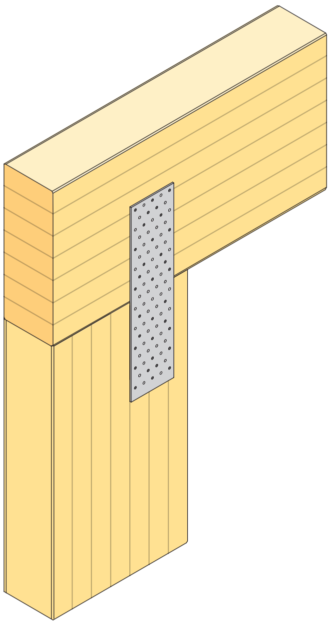


Figure 8.16 Example of a glulam post-beam connection with nail plates on both sides

- Fix the nail plate by nailing or screwing 2–3 anchor nails or anchor screws into the holes that form the limit of the edge distance. Now, when using a nail gun, the boundary is clearly visible and the risk of incorrect nailing is reduced. It is not acceptable to pull out incorrectly nailed or screwed fasteners.
- Nail or screw the outer edges of the nail plate first and continue inwards towards the centre. Once the glulam beam is installed, check the edge and end spacing again before giving the joint a final nail or screw.

Glulam manufacturers can supply steel fittings adapted to the specific project, with only the holes required for the capacity of the fitting. This makes it easier to install them correctly, as there should be fasteners in all the holes. Checking edge distances is also easier when the fitting is designed with the right number and location of holes. These fittings also make inspections simpler as there is no need to count the number of fasteners, just as long as you ensure that all the holes are filled.

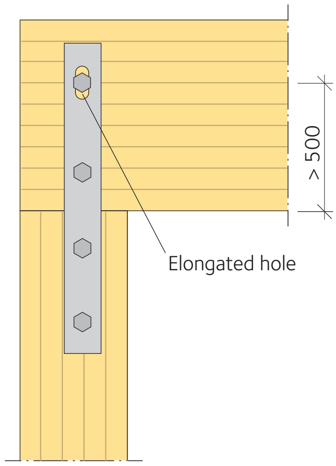


Figure 8.17 Example of glulam post-beam connection with flat steel plates and fastening with coach bolts

8.2.7 Fixing glulam posts to glulam beams with flat steel cover plates

Steel cover plates for joining glulam posts and beams are always used in pairs and may be profiled. The flat steel plate, for example measuring 8 × 80 × length, is the most common option, although the chief structural engineer calculates the actual dimensions and specifies the type of screw needed for the bracket.

The preferred fastener is often a coach bolt, which requires drilling a suitable through-hole. The hole must be drilled at a right angle to meet the fitting on the other side.

If the plates go more than 500 mm up the glulam beam, the bolts at the level above 500 mm should go through oval holes to allow the glulam beam to expand and shrink without the risk of cracking.

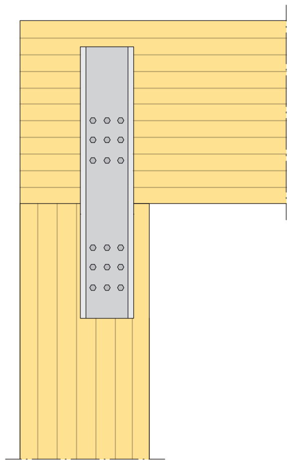


Figure 8.18 Example of glulam post-beam connection with UPE profile plates and hexagonal wood screws

8.2.8 Fixing glulam post to glulam beam with UPE profile plates

Steel plates with a U-shaped UPE profile can be drilled out to take hexagonal wood screws of smaller dimensions, with multiple screws arranged in groups.

The hexagonal wood screw is self-drilling, so there is no need to pre-drill the glulam. However, the plate must be placed in the correct position and direction before you can screw it in place.

8.2.9 Fixing a secondary beam to a glulam primary beam with a wood screw joint

Special self-drilling wood screws can be used to achieve hidden joints and to reinforce notches and holes. The universal screw is a wood screw that comes in various different sizes and lengths, with a thread at both ends and a short unthreaded section in the middle. The universal screw does not have a pronounced head for easy countersinking, but having threads in both pieces of wood creates a strong joint. The strength of the universal screw is best utilised by positioning the screws so that they are under tension.

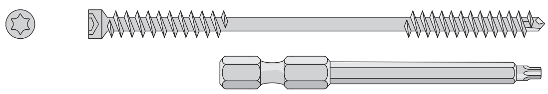


Figure 8.19 Double-threaded universal screw
With upper and lower threads to anchor two pieces of wood. No need for pre-drilling.

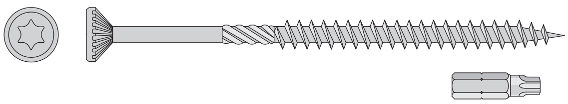


Figure 8.20 **Wood construction screw**
With specially designed threads. No need for pre-drilling.

Universal screws must always be installed so that the unthreaded part of the universal screw lies in the joint between the glulam elements. The universal screw is tightened to its correct position using a torx bit. Since the universal screws almost always have to be countersunk in the glulam, different length bits are used for the right function.

Driving in universal screws is relatively heavy going, so a low-speed corded screwdriver is the best option. Powerful battery screwdrivers can also work if the torque capacity is high enough (at least 70 Nm).

Wood construction screws are available in various designs and work like a normal wood screw. They do not have threads at both ends, but the screw head provides anchorage in one part of the joint. This screw type also has a narrower shaft so it easily passes through the wood at the joint. It is also available in a fully threaded version.

8.2.10 Fixing glulam floor joists to a glulam binder with a wood screw joint

The advantage of this type of fixing is that it is concealed, making it suitable from a fire safety point of view. Suggested procedure:

- Mark on the glulam binder where the glulam floor joists will connect.
- Set up a temporary support (mounting block) for the glulam joist.
- Offer up the joist and fix it so that it does not move when the universal screw engages the other part – you may have to back up and retighten to get a tight connection. Sometimes it can be useful to fix the joist first with a short wood construction screw, which can then be removed once the joint is fully screwed in place.
- Mark on the binder where the universal screw should be placed – the aim is for the unthreaded part to sit in the joint between the glulam elements. The universal screw should usually be at an angle of 45 degrees; a bevel gauge will help you check the direction when tightening the screw. Calculate how far the universal screw should be tightened so that the unthreaded part ends up in the joint between the glulam elements, unless this is shown in a structural drawing. Choose a suitable length of bit and mark on the bit how deep the universal screw should be inserted.
- Start by screwing the universal screw from the glulam binder into the floor joist and check that the contact with the binder is sound. Then screw from the floor joist into the binder. If there are only a couple of universal screws in the joint, these should be centred. If there are to be more than two universal screws in the same joint, they must be positioned so that the edge distance and the spacing between the universal screws are correct according to the structural drawing or instructions from the screw manufacturer.
- Check that the joint is rigid, as it is of functional importance that the glulam floor joist connects tightly to the glulam binder in order to take up the force that arises from the universal screws being at an angle.

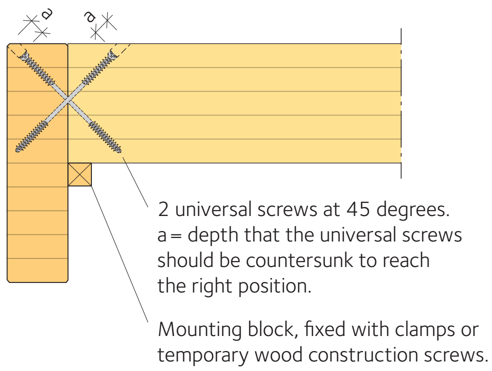


Figure 8.21 **Example of fixing a glulam floor joist to a glulam binder with a wood screw joint**

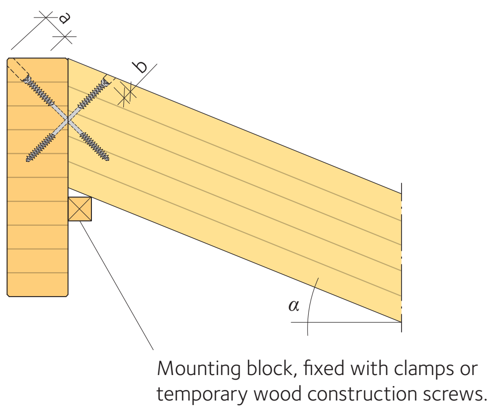


Figure 8.22 **Example of fixing a glulam roof beam to a glulam binder with a wood screw joint**

8.2.11 Fixing a glulam roof beam to a glulam binder with a wood screw joint

Using the same method as for glulam floor joists, any secondary beams can be installed provided that the parts to be connected are carefully cut.

Fastening detail in a bandy hall with a glulam frame.

Glulam arches with glulam gable posts and purlins.

While the glulam elements have slightly different angles here, this does not affect the position of the fixings. However, it can be more difficult to determine the entry hole and what reference to use for the angle, plus the two universal screws need to be sunk to different depths. Glulam beams can also be mounted against posts if they can be accessed from the back of the post, thus achieving a hidden joint.

Manufacturers of this type of wood screw offer special jigs that make installation easier, particularly if there are a large number of universal screws.

8.2.12 Fixing a glulam gable rafter to a gable post with universal screws

Glulam gable rafters usually sit in a notch in the glulam gable posts and must be anchored to the gable posts with fasteners to deal with wind load. Universal screws are inserted from the outside by screwing at a right angle through the gable rafter and into the gable post. Once again, the unthreaded part should end up in the joint between these two glulam elements, so that the threaded parts of the universal screw are embedded in each timber section. This is a simple and flexible solution as no pre-drilling is required, provided you have access to a screwdriver with high torque.

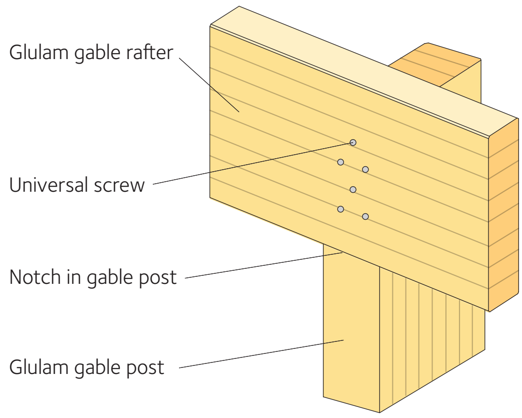


Figure 8.23 Fixing a glulam gable rafter to a glulam gable post with universal screws

Preparation for lifting glulam elements

Preparation for lifting a glulam truss.

9.1 Important advice before final glulam installation

Various preparations before lifting the glulam elements into place are essential to achieve correct, safe and fast assembly.

This pre-assembly may consist of several steps and is carried out while still working on the ground. The best results are achieved if the glulam element can be placed at a good working height.

The following should be done before final glulam installation:

- Measure and mark where other building elements, such as load-bearing plates, will connect.
- Install fittings for any purlins, shoes for compression struts, fittings for wind braces, etc.
- Ideally, fit nail plates to the tops of glulam posts before lifting.
- Decide whether to keep the transport packaging on the glulam element as weather protection or to remove it.
- Consider whether any other local weather protection should be used.
- Install moisture protection at the foot of glulam posts, if this has not already been done by the glulam manufacturer.
- Prepare for temporary bracing by installing slings and straps or cables that will accompany the lift.

With a composite structure, such as a glulam three-hinged truss with steel ties, pre-assembly is a major step. The entire truss is assembled horizontally, including the lifting beam. Fittings for purlins, fixings for wind trusses, tensioning straps for bracing, etc. are also installed before the lift.

Assembly of glulam frames

10.1 Installing glulam posts

Glulam posts that are connecting to concrete must be provided with some form of moisture protection at the foot of the post to prevent the absorption of moisture from the concrete or other moisture-absorbing substrate. Tempered wet-process hardboard or a plastic sheet nailed to the end wood are acceptable solutions that prevent moisture absorption, discolouration and moisture damage at the foot of the glulam post.

Initially applying a full layer of adhesive between the moisture barrier and the glulam post effectively seals the end wood to protect against moisture absorption and discolouration.

The use of bitumen felt is a common method of moisture protection between wood and concrete. However, this felt does not seal the end wood in the same way as tempered wet-process hardboard, and it is easy for the felt to end up poorly fitted, as it tends to slip during installation of the glulam post. Bitumen felt also does not work particularly well, as water can run down the glulam post and sit on top of the felt. It is therefore best to use 4.8 mm tempered wet-process hardboard or a suitable type of plastic sheeting for the moisture protection at the foot of the glulam post.

Note that glulam posts are at an increased risk of damage in the form of impact marks after installation, as there is usually a lot of other construction work going on in their vicinity. Care should therefore be taken to protect vulnerable sections, route vehicles a suitable distance away from glulam posts and, where necessary, provide the posts with temporary protection against damage.

10.1.1 Different types of glulam posts

A hall structure usually has several different types of glulam posts.

- Glulam primary posts supporting the primary beams in the roof. A distinction is made between:
  - Hinged glulam posts.
  - Fixed glulam posts.
- Glulam gable posts – placed in the gables to form the wall frame:
  - Usually hinged posts.
  - Rarely fixed posts.
- Glulam windposts – stand between the primary posts to hold the outer wall in place:
  - Almost always hinged posts.

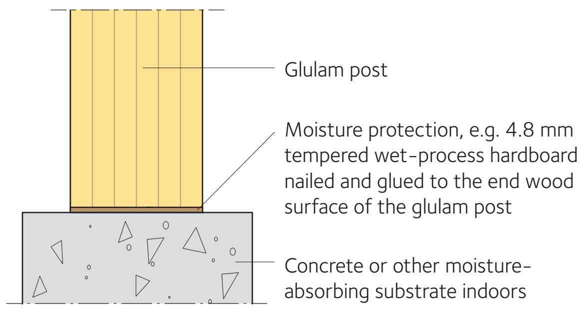


Figure 10.1 Moisture protection for the foot of a glulam post indoors

Installing a glulam post with steel plates set into the post shoe.

Assembled glulam posts with UPE profile plates at the top.

Hinged glulam posts have fittings that are hinged at both ends. Articulated glulam posts require stabilisation in both directions until structural stabilisation systems or building components are installed.

Fixed glulam posts have fittings that are firmly anchored to the foundation and hinged fittings at the top of the post. The fitting at the foot of the post is designed to be fixed in the stiff direction of the glulam post but to act as an articulated joint in the weak direction of the post. The fittings often consist of steel cover plates that go up the glulam post about twice the depth of the post. Fixed glulam posts are rigid in their stiff direction and do not need to be stabilised in this direction after they are installed. In the weak direction, however, stabilisation is required both during assembly and in the use phase.

Glulam posts are usually vertical and have to be raised from a horizontal position. Make sure that the foot of the glulam post is on a solid surface. The glulam post is fitted with a cross-member on the side where the slings will be looped around. The post will hang at a slight angle, but it is usually possible to guide it into the fixing and then raise it to a vertical position. Alternatively, you can drill a hole through the glulam post and insert a steel rod to take the slings, allowing you to make the glulam post hang more vertically.

Fixed glulam posts are inserted into the fitting and adjusted to their correct position, after which the fasteners are immediately installed. It is essential that the glulam post is in precisely the right position at this stage, as it cannot be adjusted afterwards. An assembly support is mounted in the weak direction of the glulam post to provide the necessary bracing and keep the post in the correct position.

The fittings on glulam hinged posts cannot handle moments of force, so they have to be stabilised in both directions, preferably with assembly supports.

10.2 Installing straight glulam beams

The beam types referred to here as straight are glulam beams with a straight underside. These may be installed horizontally or on an incline.

Glulam beams referred to as pitched beams, tapered beams or open-web trusses are installed in a similar way and are also covered by this description.

Glulam beams can be described as freely supported when they rest on two supports, or continuous when they are supported on more than two. They may also have brackets at the ends, but the principle of assembly is the same.

Installation is easiest if the beam is horizontal and the glulam posts have a horizontal contact area, as this makes it simple to achieve the correct positioning.

With an angled contact point, it is more difficult to fix the glulam beam in the right position. Mark the location of the contact point on the beam. If necessary, a removable block can be screwed on as a counter support.

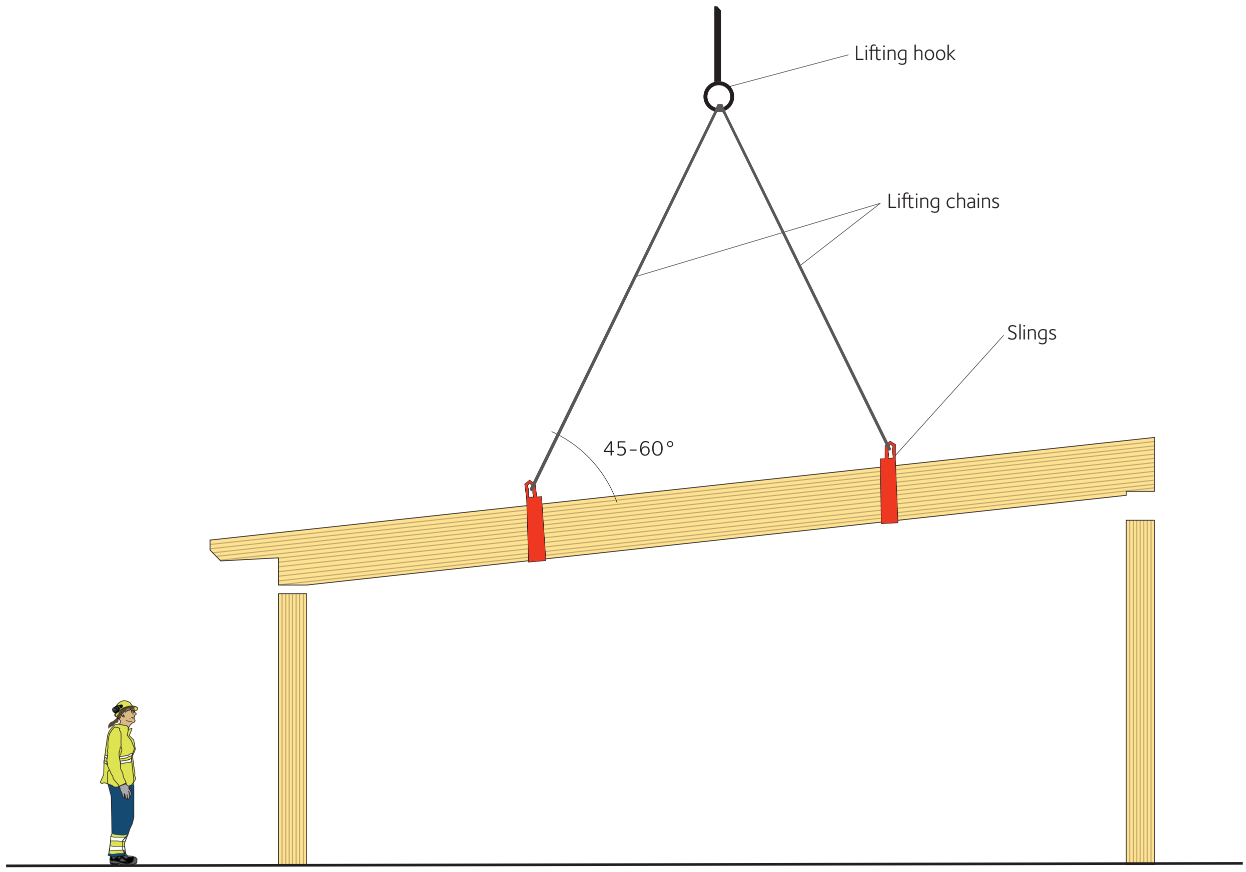


Figure 10.2 **Principle for installing a glulam beam on glulam posts.** The glulam beam is being lowered onto the glulam posts.

Glulam beams that will be sitting on an incline should be lifted so that their angle when hanging from the crane is relatively similar to the angle of the beam in its finished position.

It is important to fix the glulam beam to the support and to brace it so that it cannot tilt, i.e. tip over. Ideally, the necessary fittings will be installed at the same time, before the crane lets go. The glulam beam should now be adjusted so that it is straight between the supports and fixed with straps or cables.

Beam number 2 in a series is installed and fixed with the help of adapted tension ties, in order to achieve the right spacing between the lines.

The distance between the compression struts, which are often made of structural timber, should only be enough to ensure that the glulam beam remains straight. It must not become crooked between the struts. A spacing of 2 – 8 m is a suitable interval depending on the width of the glulam beam. Once the bracing and glulam beam are fixed in their correct position, the crane can release its hold.

It is best to begin at the location of the final, permanent wind stabilisation and use this as the starting point.

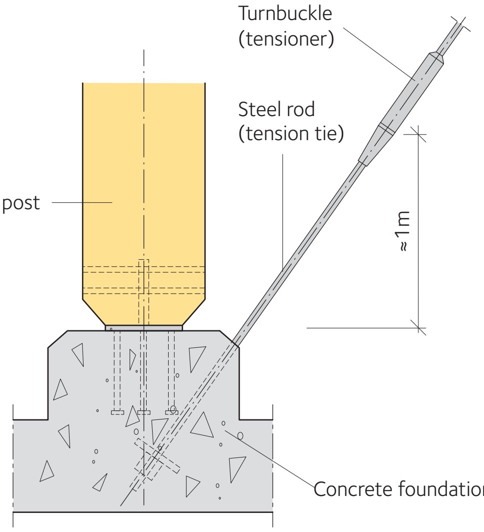


Figure 10.3 Example of connecting a diagonal wind brace to the foundation. A turnbuckle (tensioner) allows for the adjustment of the wind brace.

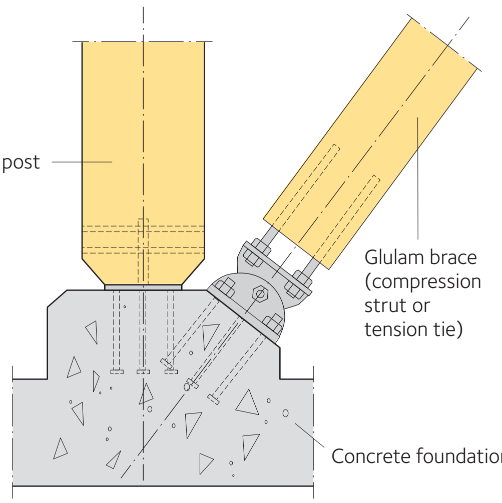


Figure 10.4 Example of connecting a rigid glulam strut with adjustable fittings to a concrete foundation

10.3 Wind braces for permanent bracing

For a building to be stable, structural elements in the walls and roof must be stiff and strong enough to transfer horizontal loads down to the foundations. Wind loads are the main horizontal load, but loads also arise from misalignment of building elements.

In the event of an incident such as fire, collision or other damage to a building element, the bracing should remain in place long enough to allow for evacuation.

Accidental loads also include loads from earthquakes, which exist in many countries but do not need to be considered in Sweden.

Only instructions for the bracing of single-storey buildings, and halls in particular, are given here.

Hall buildings generally do not have internal load-bearing walls that can provide the bracing, so they require bracing in both the roof and external walls.

Fixed glulam posts in the side walls ensure that the building is braced in one main direction, while wind braces in the roof between two primary glulam beams, and wind braces in the side walls between two primary glulam posts, ensure that the building is braced in the other main direction. In long buildings, e.g. 40 m or longer, wind braces may be required in several frame voids.

Load-bearing trapezoidal metal sheeting used as secondary support between glulam roof trusses can usually be arranged so that it forms a stiff panel. This then transfers the horizontal loads out to the wind braces in both the side walls and gable ends.

The dimensions and drawings for the metal sheeting and its fixings are usually provided by the metal supplier, as solutions vary depending on the manufacturer.

Having a wind brace in the roof structure that covers the entire building is an alternative solution, but this is not discussed in *The Glulam Handbook Volume 4*.

10.3.1 Wind brace in side walls

Ground anchoring can be achieved in various ways, depending on the design of the foundation structure. From an installation point of view, it is useful if you can have a tensioning device and tie that runs down to the foundation, as this makes it easy to adjust the glulam frame so that it is completely vertical. It is also easy to check and adjust the tie afterwards.

A projecting tie with a left-hand thread and a turnbuckle (tensioner) is the best design, *see figure 10.3*. There are also other ways of setting up a tensioning device. A structural drawing should show the method prescribed by the chief structural engineer.

If the steel diagonals are replaced by a rigid brace made of glulam or profiled steel, there will be no cross-bracing, but this type of stay is sufficient for loads in both directions. An adjustable brace is beneficial during installation.

The way that braces are connected to glulam roof beams varies with different solutions, which should be shown in the structural drawings. The most common solution is to drill a hole in the glulam roof beam at the same angle as the brace. Screwed to the side of the glulam roof beam is a half-moon shaped bracket on which the brace's washer rests, *see figure 10.5*. In some projects, the glulam roof beam is prepared with wooden cleats and steel washers, *see figure 10.6*.

Some braces have so little load that the washers can be countersunk into the glulam elements. This requires recesses to be made that ensure good contact between the washer and the glulam, which is why they are usually round.

10.3.2 Wind brace in gables

The incline of the gable rafters makes the wind braces asymmetrical, giving different lengths and angles for the ties.

The connection to the foundation is the same as for wind braces in the side walls. The brace is fixed to a forked bracket that is mounted on the gable rafter, *see figure 10.7*. It is advisable to fit this before the glulam beam is lifted up, making sure that the forked bracket is mounted at the same angle as the tie rod. There is some scope here to tension the wind brace, but space is very tight in the fork. There are also other ways of connecting the braces to the glulam gable rafters.

10.3.3 Procedure for installing wind braces in walls

The wind braces are relatively long at 6 – 10 m, so best practice is to have two people involved in the installation, as well as the crane operator who has to make sure the lift is correct.

- Prepare by screwing together the joined cross-pieces and picking out the necessary accessories, washers and nuts. When working with braces, wear work gloves and replace them with clean ones before proceeding with the glulam elements.
- Place the strut in the pre-installed hangers or complete an alternative form of attachment. Then check that the spacing is correct in the void for the wind brace. Anchor the strut so that it is secure while the steel rods are being installed.
- Insert the steel rod from below and fit the washer and nut on the upper end. Then screw it together with the turnbuckle (tensioner) for the part attached to the foundation. Try to get an equal amount of thread from both ends of the steel rod into the turnbuckle – there should be room in the turnbuckle for more tightening. Now use the steel rod to adjust the glulam posts vertically, by tightening and loosening the turnbuckle.
- Check how much thread is present in the different cross-braces and note this for the self-inspection.

The same procedure applies to gable wind braces, but in this case the glulam gable rafter acts as a strut and the steel rods should be attached to the pre-assembled fork brackets if this type of connection is used.

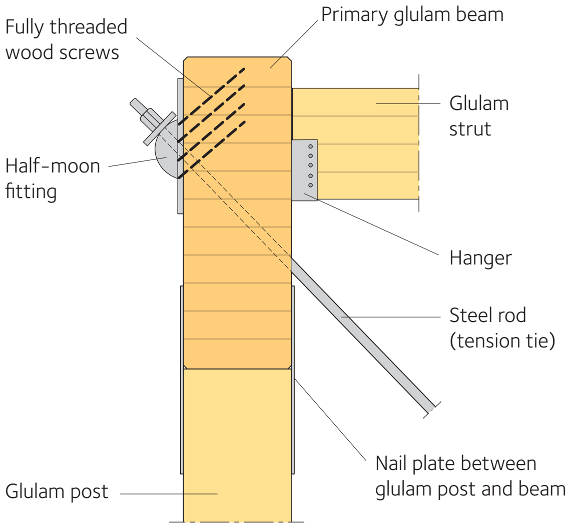


Figure 10.5 Similar connection as below, but with the half-moon fitting

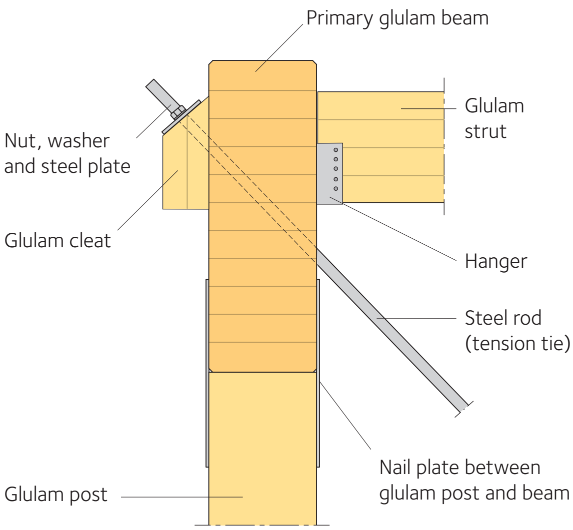


Figure 10.6 Glulam roof beam with prepared glulam cleat, nut, washer, steel plate and pre-drilled hole for diagonal steel tie rod

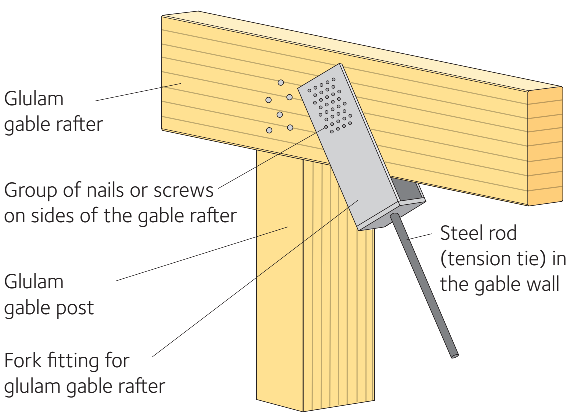


Figure 10.7 Fork bracket for fitting a wind brace to a glulam gable rafter

Fork bracket in wind brace for a glulam frame.

Fixing detail for wind brace in the roof of a glulam frame.

10.3.4 Wind braces in roofs – wind trusses

Stabilising the gables against wind load is best achieved by having a wind truss between two glulam roof beams.

Glulam primary beams are used as tension and compression elements, connected to each other by glulam compression struts and steel tension rods, which together form a rigid unit.

The truss is placed in the same void as the wind braces in the side walls, as it is necessary to channel the load from the roof via the wind braces in the walls down to the ground.

10.3.5 Procedure for installing wind trusses in roofs

The glulam roof beams should be prepared with holes and fittings before the glulam beams are lifted onto the glulam posts.

- Start by fitting the glulam struts in their hangers or by alternative means between the primary beams. Check that the spacing between the struts is correct.
- Prepare by screwing together the joined cross-pieces and picking out the necessary accessories, washers and nuts.
- The wind braces are most easily installed from a lift, possibly with lifting assistance from a crane.

Table 10.1 shows the weights of steel rods in different dimensions.

The problem is not that the rods are heavy, but that they are so flexible that they droop considerably between the lifting points, whether a crane or a person is doing the lifting.

Insert the steel rod into one glulam roof beam, far enough to align the other end with the next glulam roof beam. Fit the washers and nuts and tighten them until the tie starts to tension up. Continue with the next cross-piece to complete the wind brace. Now the straightness of the glulam beams can be adjusted by tightening the diagonal braces to different degrees. Once all the cross-pieces have been tightened, the truss in the roof will serve as a good starting point for further assembly.

As a final measure, you should check that the wind braces in the side walls are still tensioned.

Table 10.1 Self-weight of steel rods of different diameters

Diameter (mm)	Self-weight (kg/m)	Self-weight 5 m (kg)	Self-weight 8 m (kg)
20	2.5	12.5	20.0
25	3.9	19.5	31.2
30	5.6	28.0	44.8
40	10.0	50.0	80.0

Glulam frame for industrial building under construction.

10.4 Checklist for assembly of glulam frames

- Use wide webbing slings for crane lifting and provide heavy glulam elements with edge protection to avoid lifting marks.
- Ensure that work gloves, slings and other lifting devices are clean and dry.
- Do not walk on surfaces that will be visible after installation.
- Check temporary bracing to secure the frame against wind and other stresses during the construction phase.
- Check that the packaging is intact if the agreement is that it will remain as weather protection.

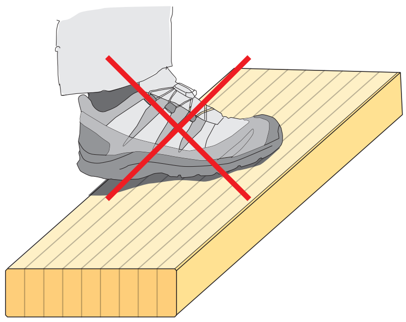


Figure 10.8 Do not walk on glulam elements
Removing dirt marks can be time-consuming.

Self-inspection of glulam assembly

Assembling a bandy hall with a glulam frame.

Self-inspection of the work carried out in accordance with an established and approved self-inspection plan must be followed up daily, as certain parts to be inspected may otherwise be encased and inaccessible.

Inspection points for the installation of fittings include the type and location of the fittings and the type and quantity of the fasteners. Since some of these elements are difficult to check after the event, it can be a good idea to document during installation that all the fittings have been correctly installed.

An important aspect of the self-inspection is ensuring that the glulam frame is vertical and with the correct spacing between the glulam elements. This should be checked continuously as it can be difficult to rectify deviations once certain other building components are in place.

Any deviations, if they exceed the applicable tolerances, should be rectified in the first instance or passed on to the assembly manager for assessment of any necessary actions.

Finishing off the completed glulam installation

On completion, the temporary bracing that is to remain should be checked before final inspection. The temporary bracing must be in good condition and there must be no loose cables or other defects. Before the finished glulam frame is handed over, it must be inspected and approved by the assembly manager.

Each worker's own workplace should be cleaned before the inspection so that the clean-up can also be checked and approved.

12.1 Inspection of glulam installation

A glulam installation should end with an inspection, although with large buildings there may be partial inspections after each stage.

The site manager or other person responsible for the construction site should be present at the inspection and approve the notes made.

The inspection should reflect the appearance of the glulam frame at the time of handover.

As a rule, the glulam frame should not have any damage or defects. Damage caused during installation should, if possible, be repaired before the inspection.

Defects in glulam elements or other materials installed should be reported to the supplier of the product in question.

The inspection report is the basis for signing off on the completed installation. The document also clarifies that the responsibility for any future damage to the installed material no longer lies with the frame's installer or installation company.

Completed glulam post and beam frame.
Timber and builders' merchant.

12.2 Final inspection of contract work

Floorball arena with glulam frame.

After the finished glulam frame has been inspected, there can be a long gap before the building is fully completed, and a lot can happen in this time, including damage to or defects in the glulam frame.
Once the entire building is completed, a final inspection and approval of the contract work must take place before the building can be handed over to the client. From the date that the building is approved, the agreed warranty period for materials and work applies.

The contract work inspection, which may take place a long time after completion of the glulam frame, includes checking that the glulam frame complies with the construction documents and contract, for example by reviewing the following points:

- Defects that may affect the load-bearing capacity of the glulam frame.
- Presence of microbial growth on glulam surfaces.
- Moisture content in the glulam. An electrical resistance moisture meter with insulated hammer electrodes can establish whether the moisture content is elevated.
- Presence or traces of insects.
- Presence of cracks and delamination.
- Presence of abnormally large cracks and gaps.
- Performance of different connections.
- Deformations, such as abnormal deflections or other changes in shape.
- Condition of fixings, e.g. presence of corrosion.

Completed frame of glulam portals with finger-jointed portal haunches. Warehouse.

Surface treatment of glulam

Surface treatment of glulam can form part of a turnkey contract or a glulam contract, in addition to the installation. To obtain a lasting, durable finish on glulam, surface treatment and associated maintenance must generally be carried out on site, especially if the glulam will be exposed to weather outdoors. Load-bearing glulam structures should be protected from prolonged precipitation and other moisture, such as ground moisture, during both the construction phase and the usage phase. However, untreated outdoor exposure may occur, for example in the case of glulam posts at entrances and glulam façade cladding.

Many surface finishes provide a degree of protection against wetting and drying out, while some also have a protective effect against microbial growth. A moisture-proof surface treatment can counteract deformations and cracking to a moderate degree, although most of the cracks that occur in glulam elements do not usually pose a risk to their strength properties. In case of uncertainty, however, the glulam manufacturer or a structural engineer should be contacted for an opinion.

13.1 Surface treatment on site

When talking about the structure of a surface treatment, a distinction is made between film-forming and non-film forming coatings:

- Film-forming coatings include glazes, wood stains, opaque paints, clear lacquers and specialist coatings such as polyurethane.
- Non-film forming treatments include distemper, colourless wood oils and chemical finishes such as iron sulphate used to accelerate the aging of a glulam surface.

A film-forming surface treatment makes the surface easier to clean and protects the glulam against mechanical damage. There are also special paints and lacquers that prevent the spread of flames and smoke in the event of a fire, see also *The Glulam Handbook Volume 1 and Part 2, pages 64 and 246 respectively*.

In general, glulam can be finished by the same means and methods used for ordinary wood. Glulam surfaces are planed, which limits the use of certain types of paints, such as distemper.

The surface moisture content must not exceed 16 % at the time of coating. Technical, economic and aesthetic considerations determine the choice in each individual case. Although pressure treated glulam provides effective protection against rot, it generally needs to be surface treated and maintained in the same way as ordinary glulam.

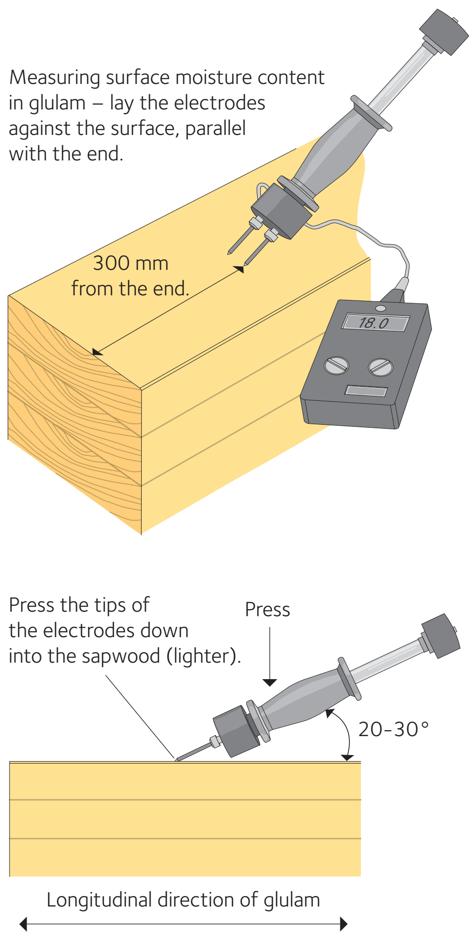


Figure 13.1 Measuring surface moisture content of glulam. It is important that the tips of the electrodes are placed at a 20–30° angle to the glulam surface.

Malmö Central Station. Railway hall built in 1923. One of the first large deliveries of glulam in Sweden. The glulam is painted. The hall is still in use today.

13.1.1 Glulam indoors – some surface treatment advice

In normally heated premises, no surface treatment of the glulam is required, unless it is to be given a colour other than the glulam's own natural pale yellow. In this case, most types of surface treatment used on ordinary wood can be used – paint, wood stains, clear lacquer or wood oil. When painting to maintain the finish, use the same type of surface treatment that was applied originally.

In premises with a high moisture load, such as swimming pools and other wet areas or other premises with a risk of condensation, it is sensible to restrict use of surface treatments that require extensive pre-treatment for maintenance, such as paints and clear lacquers. Instead, choose a suitable wood stain or wood oil, which is more maintenance-friendly. *See also table 23 in The Glulam Handbook Volume 1, page 70*.

13.1.2 Glulam outdoors – some surface treatment advice

Untreated glulam should be avoided outdoors unless it is protected from the weather. Even if treated with an unpigmented coating (colourless wood oil or clear lacquer), the surface will turn grey after a period of outdoor exposure. An untreated glulam surface can absorb moisture from precipitation, meltwater and splashing water, leading to varying degrees of discolouration, deformation and cracking.

The main degradation factors in outdoor exposure of glulam are sunlight, precipitation, dirt and soil moisture. Alternating rain and sunshine put great stress on glulam. When exposed to sunlight, a surface can quickly reach a high temperature – dark surfaces can climb to 70 °C. This causes severe drying of the glulam surface and associated movements, creating a risk that the glulam and any film-forming surface treatment will gradually begin to crack.

Glulam products intended for outdoor exposure, such as exterior glulam cladding, can be supplied with an industrial treatment already applied, ready for finishing after installation. *See also table 24 in The Glulam Handbook Volume 1, page 71*.

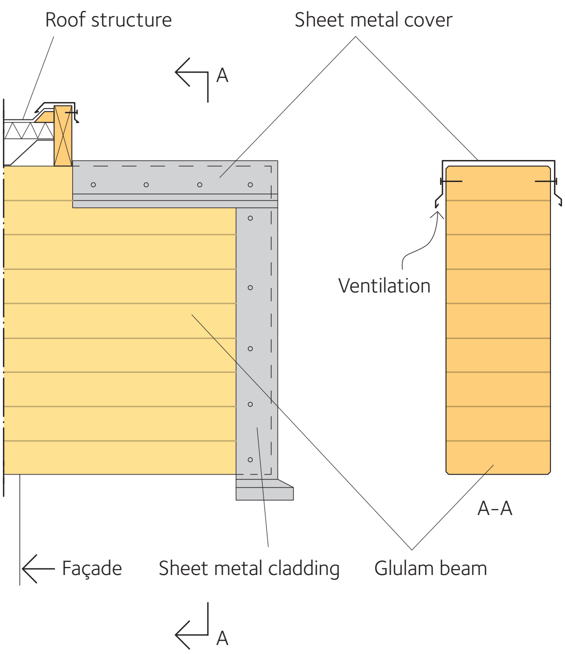


Figure 13.2 **Projecting glulam roof beam with sheet metal cladding on the façade**

13.1.3 Avoiding cracking in glulam

Minor cracks, known as checks, are generally so small and superficial that they are not a major concern. Larger cracks allow water to quickly penetrate the interior of the glulam, as well as providing pockets for damp debris and dirt that can accelerate microbial growth.

The risk of rot is particularly high on horizontal surfaces and in large cracks where water can stand. Cracks that have appeared should be filled with suitable material to prevent further cracking, or clad in sheet metal or something similar.

Long-term damp issues can be minimised in the first instance through the right building design and construction techniques. Warming from heat pipes or hot air injection carries the risk of localised dehydration and cracking.

Rapid changes in moisture content can be mitigated with a moisture-proof cladding or finish, *see example in figure 13.2*.

End wood surfaces absorb moisture about 20 times faster than other wood surfaces. Glulam elements that have exposed end wood surfaces and upper sides must generally be furnished with a ventilated cladding, such as sheet metal. If this is not possible, the exposed surfaces should be regularly treated with a moisture protection product, such as a penetrating primer or a wood preservative product with an equivalent effect.

13.1.4 Counteracting degradation by UV radiation

Using a pigmented surface treatment gives better protection against UV radiation. The higher the pigment content, the better the protection — paint layers with a flawless topcoat provide optimal UV protection and good durability. Wood stains provide only limited UV protection and thus less durability than paint systems, but on the other hand are easier to maintain.

Clear lacquers and colourless wood oils generally provide inadequate protection against UV rays and should not be used on glulam exposed outdoors, which is difficult to replace, unless you consider the surface weathering to be unacceptable. Clear lacquer on exterior glulam can soon begin to crack and flake off, making maintenance more difficult. There are, however, clear lacquers with built-in UV filters to prevent degradation. In exceptional contexts, such as the spectacular Metropol Parasol building in Seville, glulam can be given a protective polyurethane coating, which is more durable than conventional coatings.

13.2 Surface treatment by the glulam manufacturer

Glulam manufacturers can offer surface treatment of their glulam products, except for the stock range, which is always delivered untreated. If the client wishes to have the surface treatment carried out by the glulam manufacturer, contact should be made at an early stage to discuss various options.

Wood stains do not soak into the relatively hard planed surface of glulam elements. They provide some resistance to the solar effects that may occur during assembly, but their durability is limited to 3—5 years of outdoor exposure.

Most types of film-forming coatings provide good protection. The glulam manufacturers offer suitable systems that work best with their production, both practically and environmentally.

Holiday home with walls of painted glulam cladding. The glulam ridge beam and binders are partially exposed to the outdoors but protected under the roof.

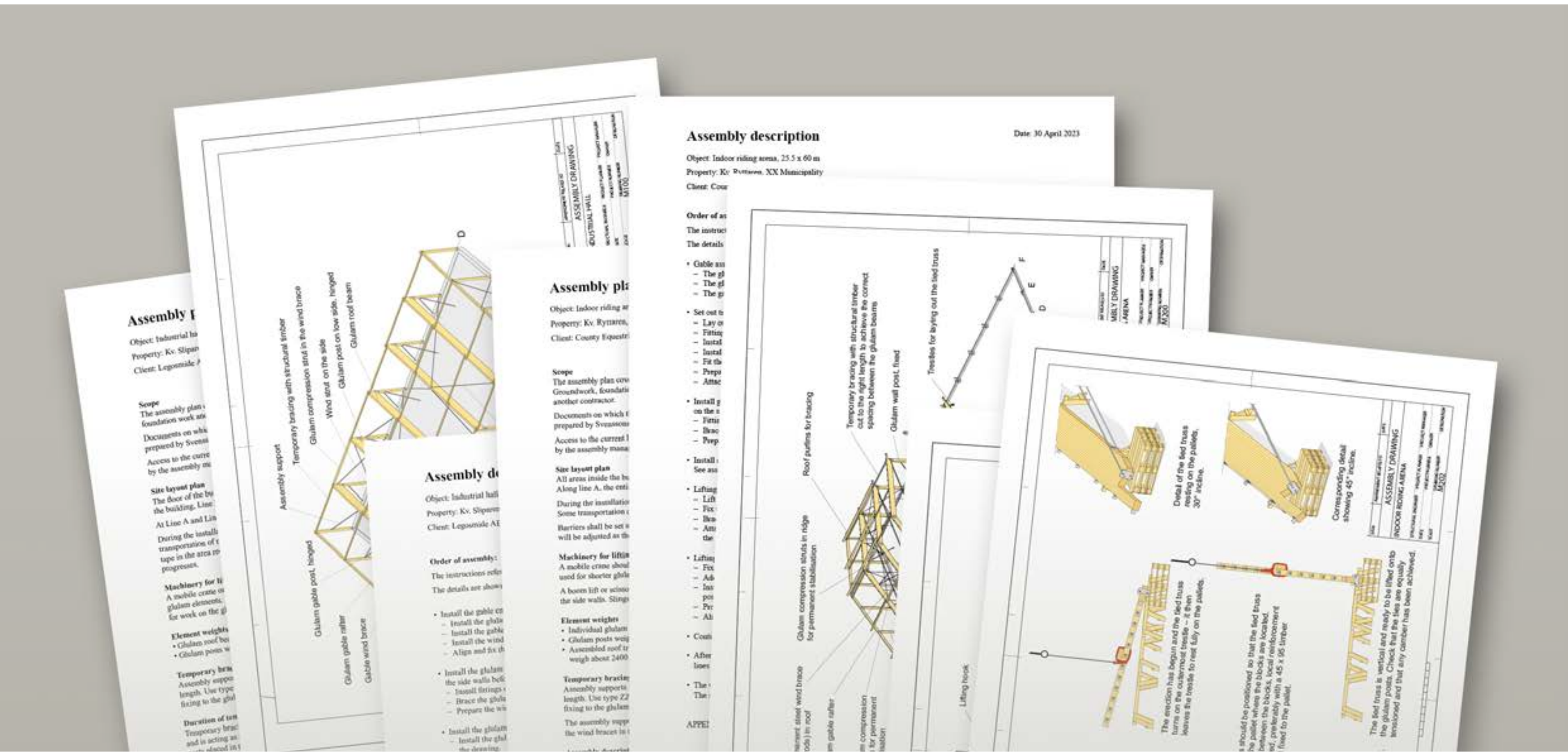
Preparation of a glulam post to be surface treated by the glulam manufacturer.

Examples of assembly plans for glulam frames

To carry out the assembly of a glulam frame in accordance with the applicable regulations, the project must have not only the necessary structural and assembly drawings, but also an assembly plan approved by the chief structural engineer and the assembly manager.

The assembly plan should also be communicated to all those involved in the installation or working in the vicinity.

Here are two examples of what such a document might look like. An assembly plan is essentially a document consisting of an assembly description and assembly drawings.



Example 1: Industrial hall with a monopitch roof

Assembly plan

Date: 30 April 2023

Object: Industrial hall, 18 x 36 m

Property: Kv. Sliparen, XX Municipality

Client: Legosmide AB

Scope
The assembly plan covers the assembly of the glulam frame for this Industrial hall project. Groundwork, foundation work and the final completion of the building envelope will be carried out by another contractor.

Documents on which the work is based are: Structural drawings and assembly drawings for the project, prepared by Svenssons Byggkonsult AB.

Access to the current list of drawings and the necessary drawings themselves will be regularly checked by the assembly manager.

Site layout plan
The floor of the building is accessible for small mobile cranes, loaders and lifts. Outside one side of the building, Line D, at one gable end, Line 1, the paved surface is only 2.0 m wide.

At Line A and Line 7, the entire surface is paved for transport vehicles and construction equipment.

During the installation phase, no other work will take place inside the building or in its vicinity. Some transportation of materials may occur along Line A on the plan. Barriers shall be set up with trestles or tape in the area required to carry out the installation. The barriers will be adjusted as the installation progresses.

Machinery for lifting and moving people
A mobile crane or telehandler will be used for unloading, internal transportation and lifting of long glulam elements. A boom lift or scissor lift will be used for assembly, and a scaffold tower may be used for work on the glulam posts along the low side. Slings and edge protectors should be used for lifting.

Element weights
- Glulam roof beams weigh around 1500 kg each.
- Glulam posts weigh between 100 and 150 kg each.

Temporary bracing during the assembly phase
Assembly supports shall be of type XX – YY. These must be able to withstand 10 kN axial force at 3 m length. Use type ZZ expander screws for anchoring to the foundation and hexagonal wood screws for fixing to the glulam posts. Ties for bracing the glulam beams must be approved for 30 kN tensile force.

Duration of temporary bracing
Temporary bracing should largely remain in place until the load-bearing sheet metal has been installed and is acting as a rigid panel. The assembly supports for the glulam posts at wind braces and the supports placed in the same direction as the wind braces can be removed as soon as the braces have been installed and tensioned.

Assembly description
The assembly order and a description of certain specific work steps have been collected in a separate document, dated 30 April 2023.

This assembly plan was prepared and approved on 30 April 2023.

Sven Svensson
Chief structural engineer
Svenssons Byggkonsult AB

Johan Johansson
Assembly manager
Montagelaget AB

APPENDIX: Assembly description

Assembly plan

Assembly description

Date: 30 April 2023

Object: Industrial hall, 18 x 36 m

Property: Kv. Sliparen, XX Municipality

Client: Legosmide AB

Order of assembly:

The instructions refer to the main lines that apply for the Industrial hall site.

The details are shown in the assembly and structural drawings for the project.

- Install the gable end in line 1.
  - Install the glulam posts and brace with assembly supports, 2 per post.
  - Install the gable rafter including the fittings for the wind brace.
  - Install the wind brace in the gable line.
  - Align and fix the gable with assembly supports and wind braces.

- Install the glulam posts in lines A and D for lines 2 and 3 (it is OK to install all the glulam posts on the side walls before proceeding with the glulam roof beams).
  - Install fittings on the tops of the glulam posts.
  - Brace the glulam posts in both directions using assembly supports.
  - Prepare the wind braces in the side walls.

- Install the glulam beam in line 2.
  - Install the glulam beam and brace it against the gable using 4 temporary braces according to the drawing.

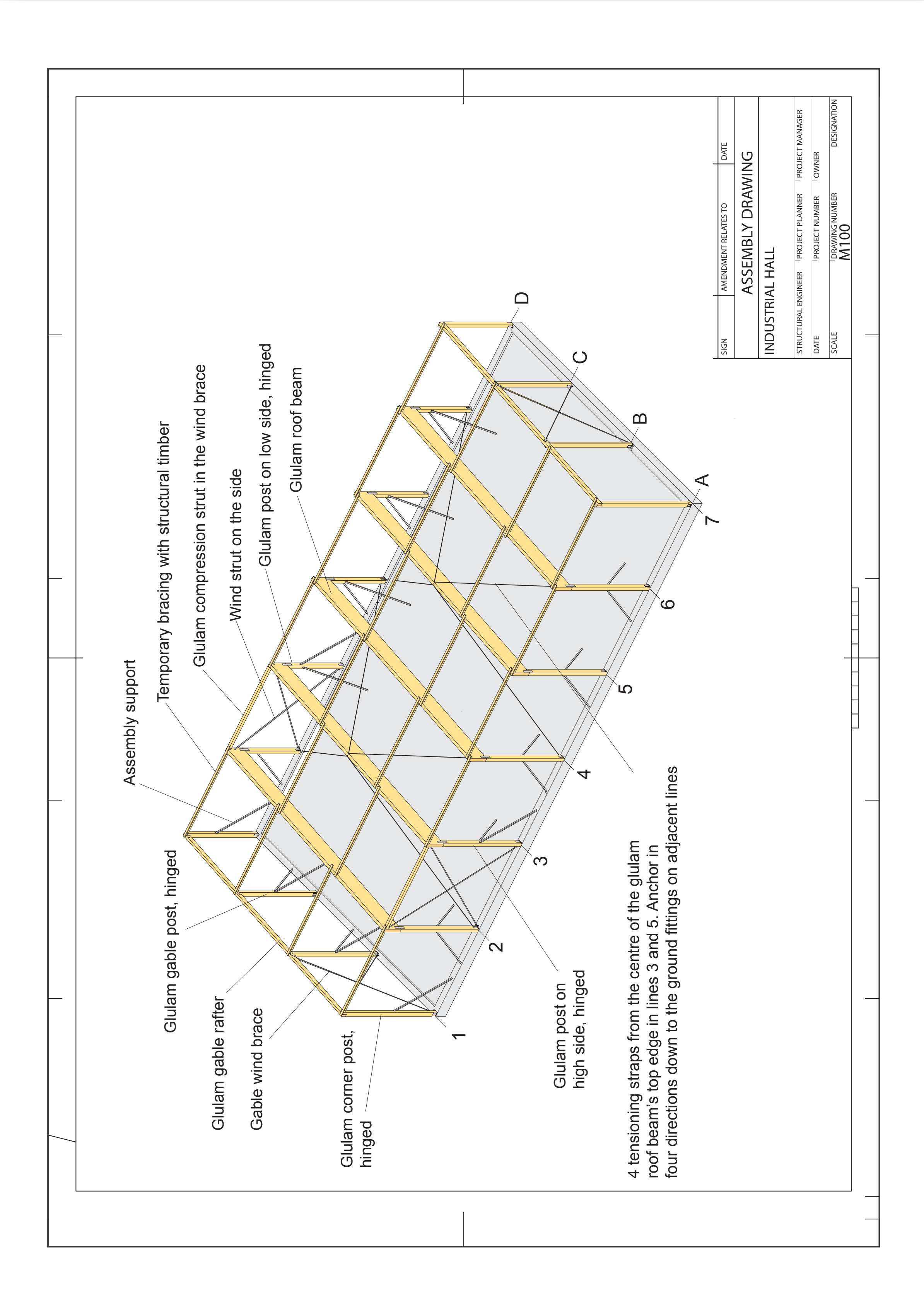
- Install the glulam beam in line 3.
  - Install the glulam beam.
  - Brace with the permanent rods to be placed in void 2 – 3, lines A and D.
  - Add 2 temporary braces according to the drawing.
  - Attach tensioning straps, 4 from the centre of the glulam roof beam’s top edge in line 3 and anchor these to the ground fittings on adjacent lines.
  - Install steel rods in the wind braces on the side walls between lines 2 and 3.

- Install glulam posts and glulam roof beams for lines 4 – 6.
  - Brace against the previous glulam roof beam with temporary braces according to the drawing.
  - Add straps to line 5 as per line 3.

- Install the gable end in line 7.
  - Install the glulam gable posts.
  - Lift the glulam gable rafter with fittings for a wind brace into place and anchor it to the tops of the glulam posts.
  - Temporarily brace the gable rafter with 4 temporary braces on line 6.
  - Install the wind brace in the gable in line 7.

APPENDIX: Assembly drawing M100.

Appendix: Assembly description.



Appendix: Drawing of assembly order and temporary bracing.

Example 2: Indoor riding arena with apex roof

Assembly plan

Date: 30 April 2023

Object: Indoor riding arena, 25.5 x 60 m

Property: Kv. Ryttaren, XX Municipality

Client: County Equestrian Association

Scope
The assembly plan covers the assembly of the glulam frame including purlins for this arena building. Groundwork, foundation work and the final completion of the building envelope will be carried out by another contractor.

Documents on which the work is based are: Structural drawings and assembly drawings for the project, prepared by Svenssons Byggkonsult AB.

Access to the current list of drawings and the necessary drawings themselves will be regularly checked by the assembly manager.

Site layout plan
All areas inside the building and 3 m outside the building are paved for the mobile crane and lift. Along line A, the entire gravel yard is drivable for both transport vehicles and a mobile crane.

During the installation phase, no other work will take place inside the building or in its vicinity. Some transportation of materials may occur in the gravel yard along line A.

Barriers shall be set up with trestles or tape in the area required to carry out the installation. The barriers will be adjusted as the installation progresses.

Machinery for lifting and moving people
A mobile crane should be used for unloading shipments of long glulam elements and a loader may be used for shorter glulam elements and palletised goods.

A boom lift or scissor lift and possibly a scaffold tower will be used for work on the glulam posts along the side walls. Slings and edge protectors should be used for lifting.

Element weights
- Individual glulam roof beams weigh around 900 kg each.
- Glulam posts weigh between 200 and 300 kg each.
- Assembled roof trusses consisting of 2 glulam beams, plus steel ties and a tie beam, weigh about 2400 kg each.

Temporary bracing during the assembly phase
Assembly supports shall be of type XX – YY. These must be able to withstand 10 kN axial force at 3 m length. Use type ZZ expander screws for anchoring to the foundation and hexagonal wood screws for fixing to the glulam posts. Ties for bracing the glulam beams must be approved for 40 kN tensile force.

The assembly supports and tensioning straps can be removed once the wind brace voids in the roof and the wind braces in the side walls have been installed.

Assembly description
The assembly order and a description of certain specific work steps have been collected in a separate document, dated 30 April 2023.

This assembly plan was prepared and approved on 30 April 2023.

Sven Svensson
Chief structural engineer
Svenssons Byggkonsult AB

Johan Johansson
Assembly manager
Montagelaget AB

APPENDIX: Assembly description

Assembly plan

Assembly description

Date: 30 April 2023

Object: Indoor riding arena, 25.5 x 60 m

Property: Kv. Ryttaren, XX Municipality

Client: County Equestrian Association

Order of assembly:

The instructions refer to the main lines that apply to the object: Indoor riding arena.

The details are shown in the assembly and structural drawings for the project.

- Gable assembly.
  - The glulam gable posts are braced with assembly supports in both directions.
  - The glulam gable rafter is lifted into place and anchored to the tops of the glulam posts.
  - The gable wind brace is installed and the position of the gable is adjusted.

- Set out trestles for roof truss lines 2 and 3, wind truss lines.
  - Lay out the glulam roof beams and connect them at the ridge.
  - Fittings for the wind braces are mounted on the glulam roof beams.
  - Install hangers for permanent compression struts.
  - Install the lower fittings for the purlins once the glulam beams are in place.
  - Fit the tensioning straps and suspenders. Check for any camber.
  - Prepare the compression struts that will be part of the wind braces.
  - Attach straps to the ridge, 2 on each side for temporary bracing.

- Install glulam posts in lines A and F for lines 2 and 3 (it is OK to install all of the pre-fabricated glulam posts on the side walls before proceeding with the tied glulam trusses).
  - Fittings for the tops of the glulam posts.
  - Brace the glulam posts laterally with the help of assembly supports.
  - Prepare the wind braces in the side walls.

- Install a temporary tie beam on the tied glulam truss. This is required to ensure a good and safe lift. See assembly drawing M201, principle for lifting a tied glulam truss.

- Lifting tied truss in line 2.
  - Lift so that the tied glulam truss rises without being damaged in the process.
  - Fix the tied glulam truss to the tops of the posts.
  - Brace the tied glulam truss against the gable using temporary struts, preferably 3 on each half of the roof.
  - Attach tensioning straps to the foot of the glulam posts on adjacent lines and adjust so that the tied truss is in the correct position along its entire length.

- Lifting tied truss in line 3.
  - Fix the tied glulam truss to the tops of the glulam posts.
  - Add the permanent strut at the eaves on both sides.
  - Install the struts in the wall's wind brace and align the glulam posts so that the tied glulam truss is positioned correctly.
  - Proceed with the installation of the permanent compression struts and steel rods in the wind truss.
  - Align the tied glulam roof trusses with the wind braces so that they are straight and plumb.

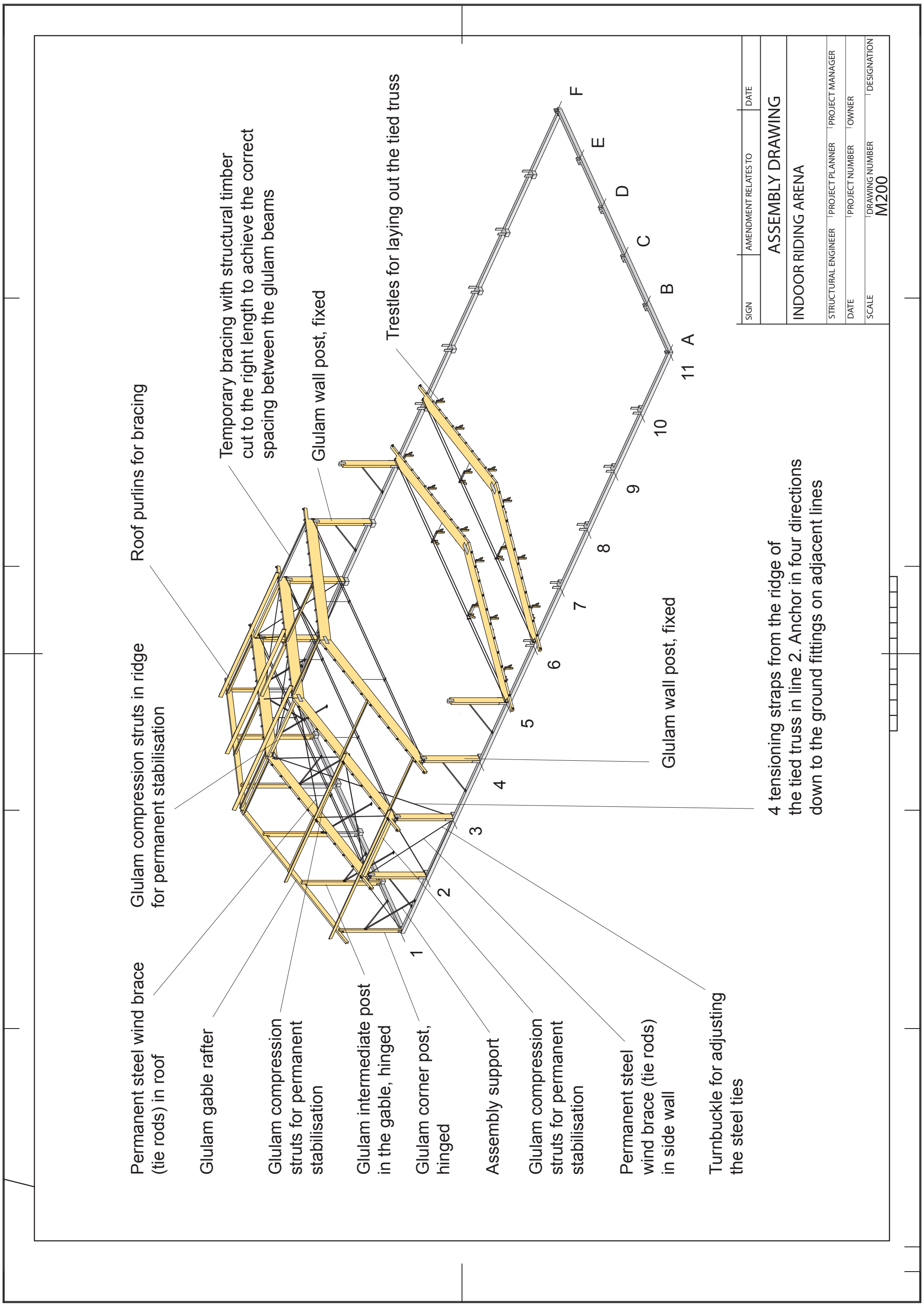
- Continue assembly with line 4 and so on, and brace with 5–6 purlin lines between the tied glulam trusses.

- After another 3 truss lines, new stabilisation should be performed with straps from the ridge down to adjacent lines to control the position of the ridge.

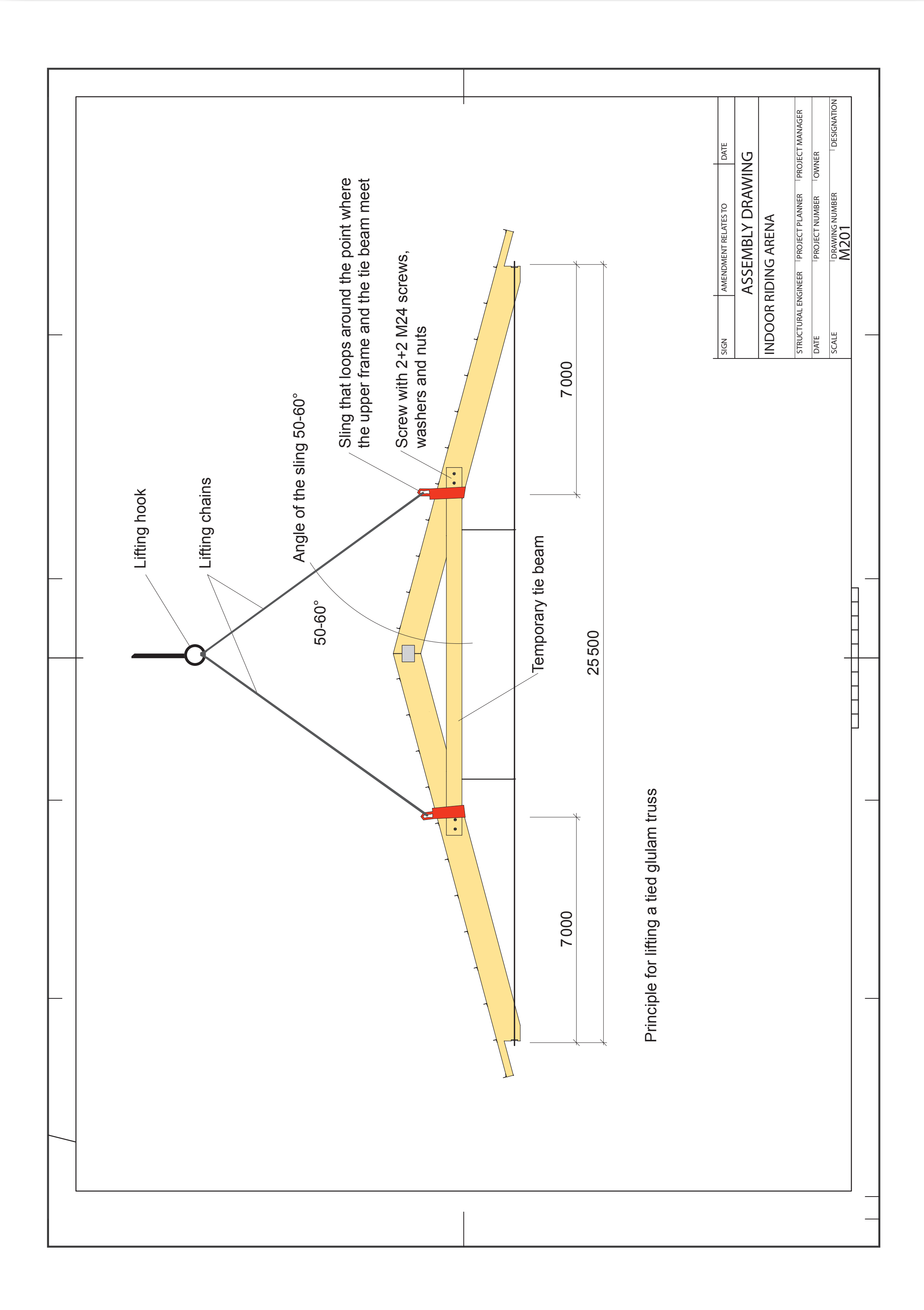
- The wind truss recurs in lines 9–10. Once this is installed, all temporary bracing material can be removed. The system of purlins for the roof structure remains to be completed.

APPENDICES: Assembly drawings M200, M201 and M202.

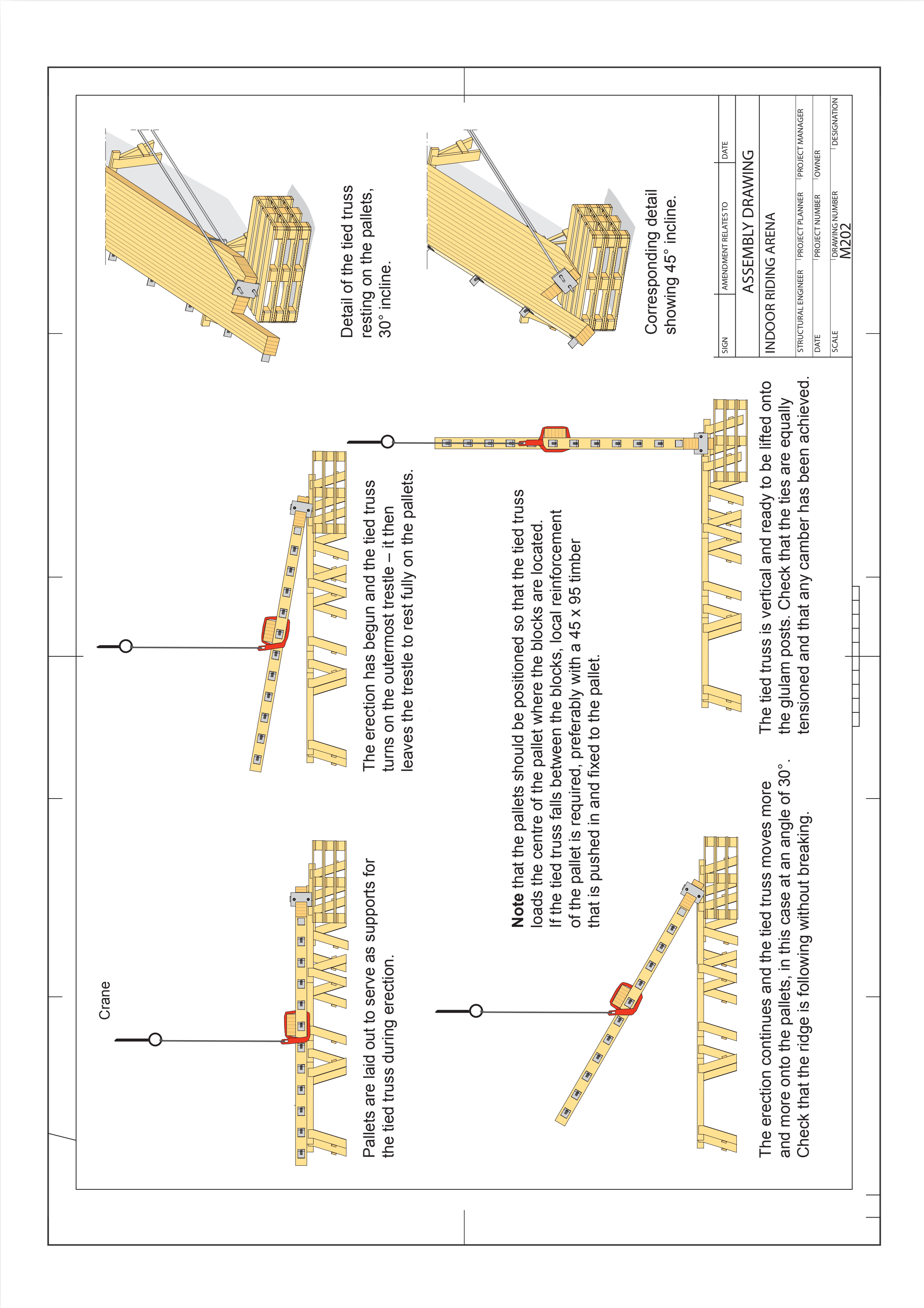
Appendix: Assembly description.



Appendix: Drawing of assembly order and temporary bracing.



Appendix: Drawing for the lifting of a tied glulam roof truss.



Appendix: Drawing for the lifting of a tied glulam roof truss.

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The raw materials come from Swedish forests and the finished products meet the European standard for CE-marked glulam. All the glulam manufacturers have an environmental declaration and are certified by accredited certification bodies.

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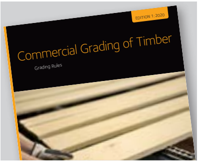

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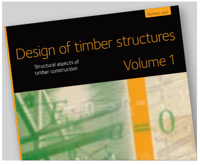

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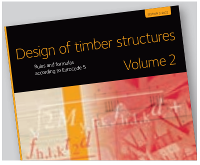

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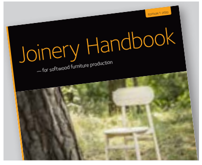

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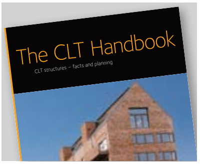

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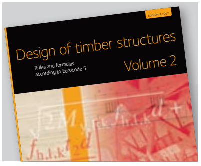

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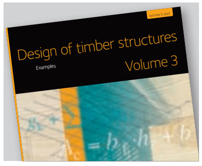

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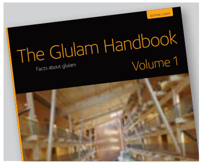

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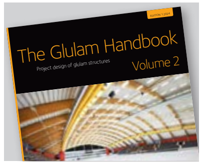

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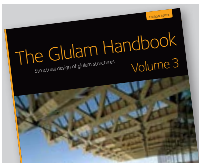

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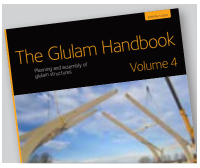

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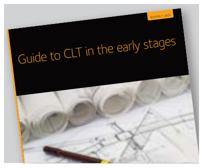

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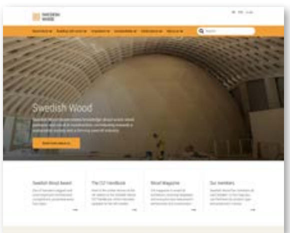

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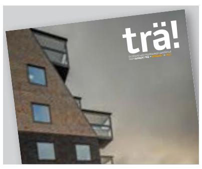

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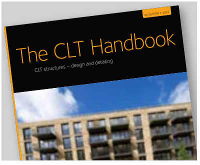

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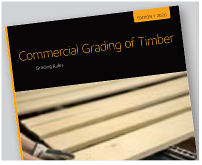

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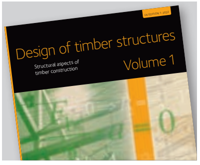

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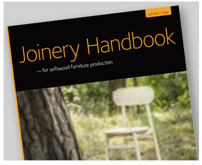

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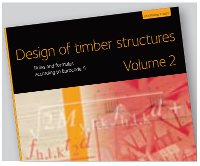

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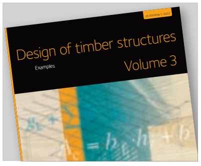

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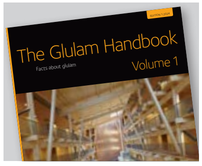

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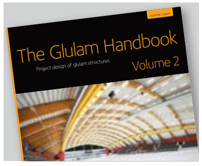

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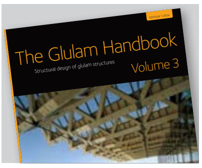

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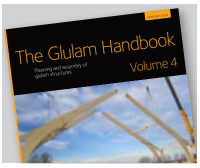

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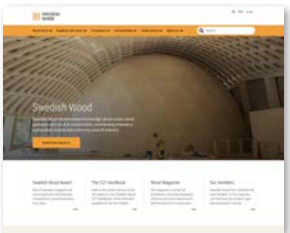

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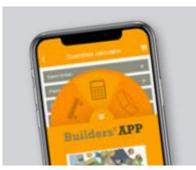

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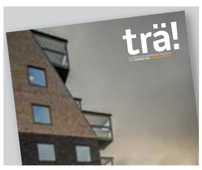

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