



Glued laminated timber in hall construction

Far-reaching possibilities

Structural systems in glued laminated timber

The following pages will give you a general overview of the fundamental static structural concepts with glued laminated timber. Important information, detailed solutions and rules of thumb for pre-measurement will be shown for planning and bidding.

Deciding on the individual system ultimately depends on the value that the builder places on the aforementioned points. The design and structural planning are hardly limited due to the versatile and easily shaped material of wood. Wood has many advantages in comparison to alternative building materials. In particular the high-quality strength class GL30c beams, as well as the precise CNC-controlled timber framing, can be designed as a support structure, including in combination with steel, filigree and transparent, open timber framing systems. The varied possibilities cannot all be presented in this brochure and should be developed by contacting us directly.

How glued laminated timber behaves in the event of fire is often completely misjudged due to its flammable characteristics. Upon combustion, a charred layer forms around a load-bearing, intact core which reduces the oxygen and heat supply, and thereby significantly delays any further combustion. According to German industry standard (DIN) 1995-1—2:2010-12, the class R 30 is mostly achieved with the structurally necessary cross section, even without any coating, which is required for steel structures. R 60 can also be cost-effectively fulfilled with glued laminated timber. Special attention must be paid to the detail of how the connections are formed because steel fasteners are often used.

The choice of roof structure or cladding is essential in deciding in favour of one of the different support structures because the roof pitch required is dictated by this. As a planning tool, in the following tables, there are recommendations for the minimum roof pitch and the distance between supports for all common roof cladding.

The systems presented cover all of the needs of modern hall construction:

- As much architectural freedom as possible
- Protection against fire
- As large a structure gauge or range as possible
- Combination with all common roofing
- Simple connection options to adjoining trades
- Cost-efficiency
- Low-maintenance
- Low dead weight with high load capacity (affordable set-up and transport costs)
- Resistance to chemically aggressive atmospheres
- High level of prefabrication, quick construction time
- Sustainable and ecological



Engineering office and administration at the Niederkrüchten factory (Timber Construction Award 2000)

Roof cladding	Minimum roof pitch*
Corrugated sheet – single-skinned, uninsulated	up to 3° without transverse joint / 3–5° 200 mm Overlap 5–20° 150 mm Overlap / > 20° 100 mm Overlap
Corrugated sheet – insulated	≥ 3° Recommendation!
Insulated or sandwich panels	≥ 5° without transverse joint from ridge to the eaves ≥ 7° with transverse joint from ridge to the eaves
Fibre cement corrugated sheets	≥ 7° or according to manufacturer specifications
Tile cover	≥ 30° without support construction ≥ 22° with support construction or according to manufacturer specifications

* The roof surface should have a continuous slope to the guttering. Roof surfaces without slopes require special measures e.g. arranging the guttering in places of maximum deflection. Where a possible blockage in the guttering could lead to the roof surface flooding, emergency guttering must be planned for the roof edge. In addition, the relevant guidelines (e.g. flat roof guidelines) must be observed.

Roof cladding		Distance between supports (with 0.65 kN/m ² of snow)	
		Laid as single span supports	Laid as multi-span supports
Corrugated sheet – Uninsulated Negative position (narrow rib up)	Type 50 / 250 / 0.75	2.00 m	2.75 m
	Type 135 / 310 / 0.75	6.00 m	7.50 m
	Type 160 / 250 / 0.75	7.75 m	9.00 m
Corrugated sheet – Insulated Positive position (narrow rib down)	Type 50 / 250 / 0.75	1.75 m	2.00 m
	Type 135 / 310 / 0.75	5.00 m	6.25 m
	Type 160 / 250 / 0.75	7.75 m	9.00 m
Insulated or sandwich panels	Type 70 / 40	3.00 m	3.84 m
	Type 100 / 60	3.50 m	4.50 m
	Type 120 / 80	3.70 m	4.60 m
Fibre cement corrugated sheets	Profil 5; a < 20°	≤ 1.15 m	-
	Profil 5; a ≥ 20°	≤ 1.45 m	-

Pitched cambered beams with straight bottom flange

As the stresses can be transferred efficiently and the profile of the beam matches the outline of the roof pitch, pitched cambered beams with a straight bottom flange are a very effective and simple roof solution. The top edge of the beam continues according to the minimum roof pitch of 2–5° which is required to ensure adequate roof drainage.

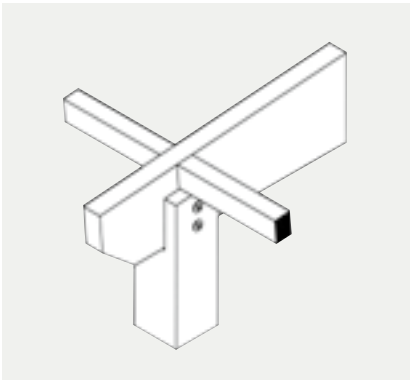
The formation of a single-edge cantilever or a duo-cantilever over both sides of the walls increases the operating efficiency of the structure, since the moment distribution is optimised. It is important to ensure the length of the cantilever does not exceed 25% of the field length. The construction of the cantilever girders can be carried out according to illustrations 1–3 (please see page 7).

In general, pitched cambered beams can be used for industrial building applications, sports halls and recreational buildings. With regard to the roof-coverings, it is possible for glulam structures to support both warm and

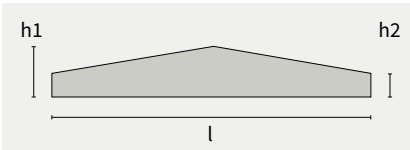
cold roofing techniques as well as non-insulated roofing options with no effect on performance and integrity.

Support for the glulam roof structure can be provided by a variety of materials – glulam timber, reinforced insitu or precast concrete or steel columns are all viable options. The columns should be installed with a fixed column base at least on one side of the building, to transfer the wind load into the foundation (please see page 20/21). To ensure services distribution whilst maintaining the integrity of the structure all openings shall be suitably stiffened utilising a plywood support plate on both sides of the holes. This avoids material splitting.

With regard to building design and setting out a width-to-height-ratio of 1:10 should be borne in mind. In addition, there may be a need for roof bracing members between the beams or consideration given to a composite action taking into account the roof components (please see page 19).



Bearing detail



Pitched cambered beam with straight bottom flange



Span	10 – 70 m
Roof pitch	2 – 5°
Usual spacing between beams (other values possible)	5 – 7 m
Beam width (per 2cm preferred dimensions)	10 to 26 cm
Cantilevers	yes
Height of components (for structural design)	$h1 = l/16$; $h2 = l/25 - l/30$
Possible fire-resistance classes	<ul style="list-style-type: none">– R 30 > unproblematic– R 60 > with additional costs
Strengths	GL 24h/c, GL 28c, GL 30c

Pitched cambered beams with hoisted bottom flange

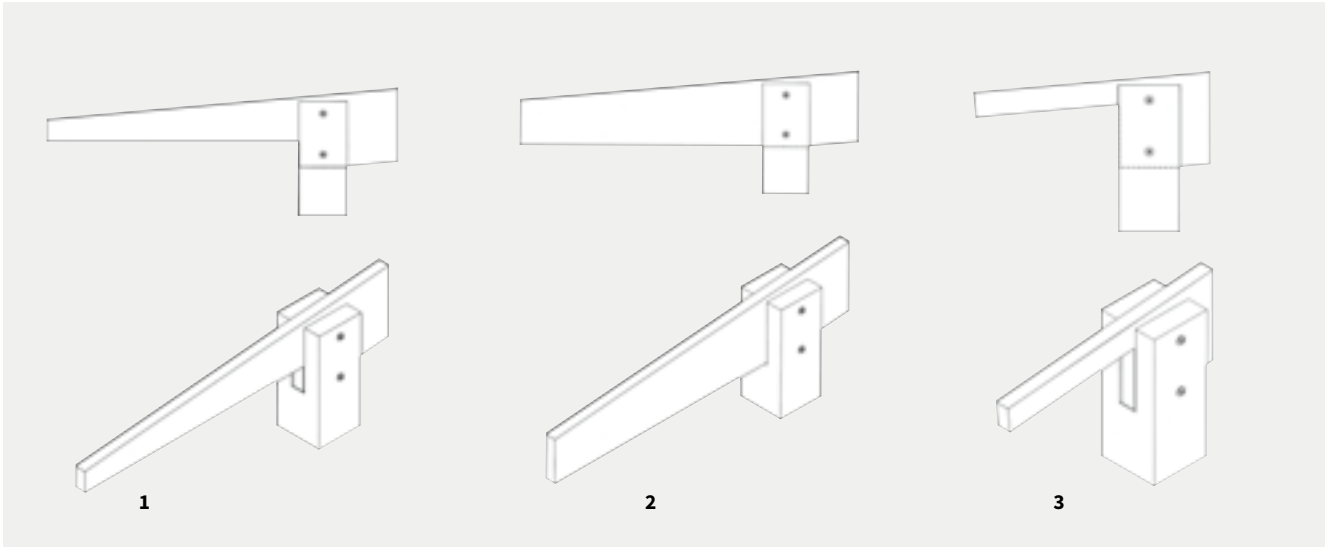
Although this kind of beam offers the same advantages as the pitched cambered beam. A further advantage of pitched cambered beams with hoisted bottom flange is that the roof pitch can be increased up to 20°. These beams could be specified where a concrete / clay tile covering is demanded. However, with the increase in roof pitch, the tensional strength shall also be increased and therefore it shall be necessary to apply threaded bolts or planking to the connection design. It is advisable to mention this procedure in the project specification. The design options are described on illustrations 1 – 3.

In general, the ridge of the gabled roof is not subject to be used for load transfer and can be replaced by a non load bearing glulam

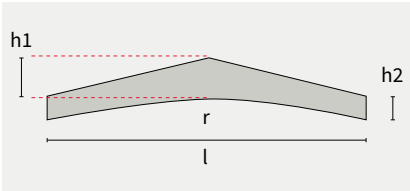
infill. If there is a top-light in the ridge area, the infill is not needed.

During the planning process it is important to keep in mind that the roof pitch is higher therefore the beams may need to be physically larger. Transportation of the building components should always be addressed early in the design. In general, the maximum height that is able to be transported by road is approximately 3.50 m.

With regard to building design and setting out a width-to-height-ratio of 1:10 should be borne in mind. In addition, there may be a need for roof bracing members between the beams or consideration given to a compo site action taking into account the roof components (please see page 19).



Different Options of Cantilevers



Pitched cambered beam with hoisted bottom flange

Span	10 – 40 m
Roof pitch	5 – 20°
Usual spacing between beams (other values possible)	5 – 7 m
Beam width (per 2cm preferred dimensions)	10 to 26 cm
Cantilevers	yes
Height of components (for structural design)	$h1 = l/14 - l/16$; $h2 = l/20 - l/24$
Possible fire-resistance classes	<ul style="list-style-type: none">– R 30 > unproblematic– R 60 > with additional costs
Strengths	GL 24h/c, GL 28c, GL 30c

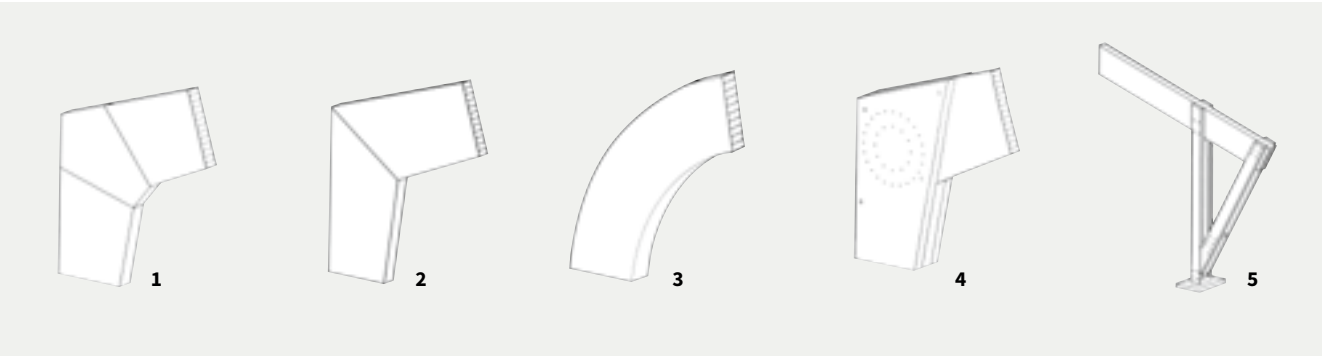
Three-hinged frame structure

Three pinned hinged frames are a very efficient form of structural design as a result of effective load transmission to ground. Given this efficiency the glulam material consumption can be kept to a minimum. Further, three pinned hinged frames are a very cost-effective solution because the building foundations can be realised at optimal cost.

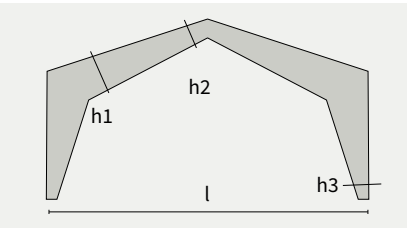
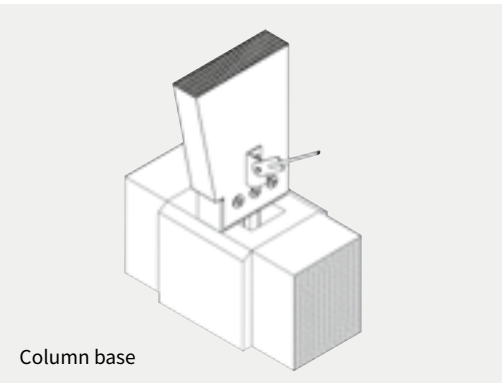
All in all, the use of three pinned hinged frames is only restricted by transport limitations and the challenge to realise a lightly loaded supporting structure. The photos left hand demonstrate that all is possible. Three pinned hinged frames are commonly used to free-span equestrian halls, recreational buildings, sports halls, industrial halls and agricultural buildings.

The bending resistant angles can be realised by specialised connection designs and arch systems (please see illustrations on the following page). It is normal practice to detail the frame whereby all connections are within the building fabric thus limiting exposure of the glulam to the elements.

Cantilever girders can be accommodated with the three pinned hinged frame structure. In equestrian applications it may be possible to add stalls for horses as an extension to the frame with a mono pitched lean-to roof addition.



1 double finger-joint
2 single finger-joint
3 curved
4 dowelled
5 dispersed



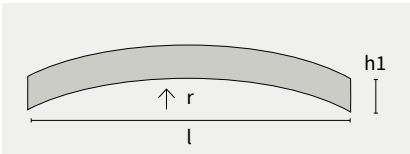
Three-hinged frame structure

Span	15 – 50 m
Roof pitch	10 – 40°
Usual spacing between beams (other values possible)	5 – 7 m
Cantilevers	– finger-joint frame – curved angle – haunch with anchor
Beam width (per 2cm preferred dimensions)	10 to 24 cm (26 cm)
Height of components (for structural design)	$h_1 = l/15 - l/22$; $h_2 = l/36 - l/60$; $h_3 = l/40 - l/50$
Possible fire-resistance classes	– R 30 > unproblematic – R 60 > with additional costs
Strengths	GL 24h, GL 28c, GL 30c

Arched beams

Arched or curved glulam beams are often used where the structure of a building is exposed as an architectural feature. With regard to cost-effectiveness, self-weight and aesthetic attractiveness, other structural components are far less suited where these criteria are demanded. Curved glulam structures allow lightweight buildings as a result of slender and simple structures and shapes. When compared to other building materials glulam is particularly easy to form into shapes and curves and does so at a significantly reduced premium.

As with all curved structures, the building designer needs to be mindful of the basic design criteria when designing with curves. Although small radii can be produced, those below 7 m attract a further premium over and above larger members. Production costs are greatly increased below 7 m when thinner timber lamellas are required to glue up the members.



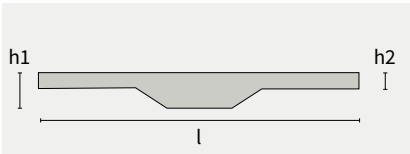
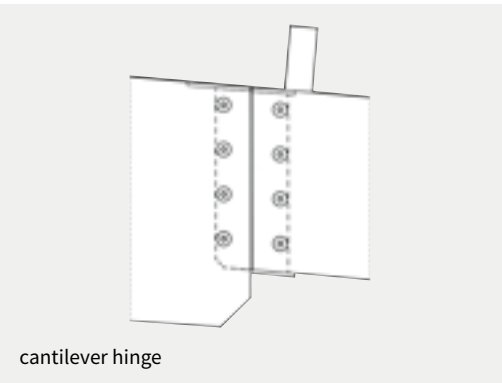
Arch beam

Span	5 – 25 m
Roof pitch	consider max. transport height and width
Usual spacing between beams (other values possible)	2 – 6 m
Beam width (per 2cm preferred dimensions)	10 to 26 cm
Cantilevers	yes
Height of components (for structural design)	$h1 = l/17$ to $l/25$; $r \leq 7$ m
Possible fire-resistance classes	– R 30 > unproblematic – R 60 > with additional costs
Strengths	GL 24h/c, GL 28c, GL 30c

Continuous beams

Continuous beams are an effective and economic solution for large span structures that may be applicable in large production halls or warehouses. For this construction continuous beams are used as the principal load-bearing elements in order to cover large parallel sections of roof. As the moment distribution of continuous beams is excellent, the bending under load and the stress concentration can be optimised. In the case of extremely large spans, joints in the glulam are factory engineered and executed on site in order to facilitate the transport of the individual structural members.

In order to ensure adequate drainage falls over the roof areas, a roof-pitch of between 2 – 5° is recommended. Depending on the application area, the internal columns to sub-divide the space and the principal external columns can be executed in different materials (e.g. fixed ended reinforced concrete internal columns whilst pin-ended timber columns are used around the building perimeter).



Continuous beam

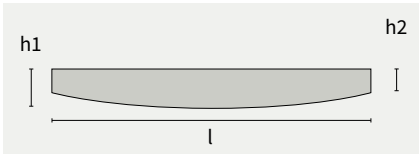
Span	10 – 60 m
Roof pitch	-
Usual spacing between beams (other values possible)	5 – 10 m
Beam width (per 2cm preferred dimensions)	10 to 26 cm
Cantilevers	possible
Height of components (for structural design)	$h1 = l/16$; $h2 = l/22$
Possible fire-resistance classes	<ul style="list-style-type: none">- R 30 > unproblematic- R 60 > with additional costs
Strengths	GL 24h/c, GL 28c, GL 30c

Fish-bellied beams

The bottom profile of these structural members has the form of a parabola and this reflects the ideal moment distribution of the beam. As a result, the stress/strain characteristics of fish bellied beams are excellent. Due to their harmonious and aesthetic shape, fish bellied beams are often used when the structure of a building is exposed as an architectural feature.

In situations like that of a single nave hall, the roof will be built as a single-pitch roof. If the hall has two or more naves with central support, a gabled roof will be realised.

Fish-bellied beams can be used as ceiling joists, floor joists and as binding beams.



Fish-bellied beams

Span	10 – 70 m
Roof pitch	-
Usual spacing between beams (other values possible)	5 – 7 m
Cantilevers	possible on both sides
Beam width (per 2cm preferred dimensions)	10 to 26 cm
Height of components (for structural design)	$h1 = l/16$; $h2 = l/20$ to $l/25$
Possible fire-resistance classes	<ul style="list-style-type: none">- R 30 > unproblematic- R 60 > with additional costs
Strengths	GL24h/c, GL 28c, GL30c

Purlins

Where it is not possible to install the roofing components between primary structural beams due to excessive centres, secondary support is provided with glulam purlins spanning between the primary members.

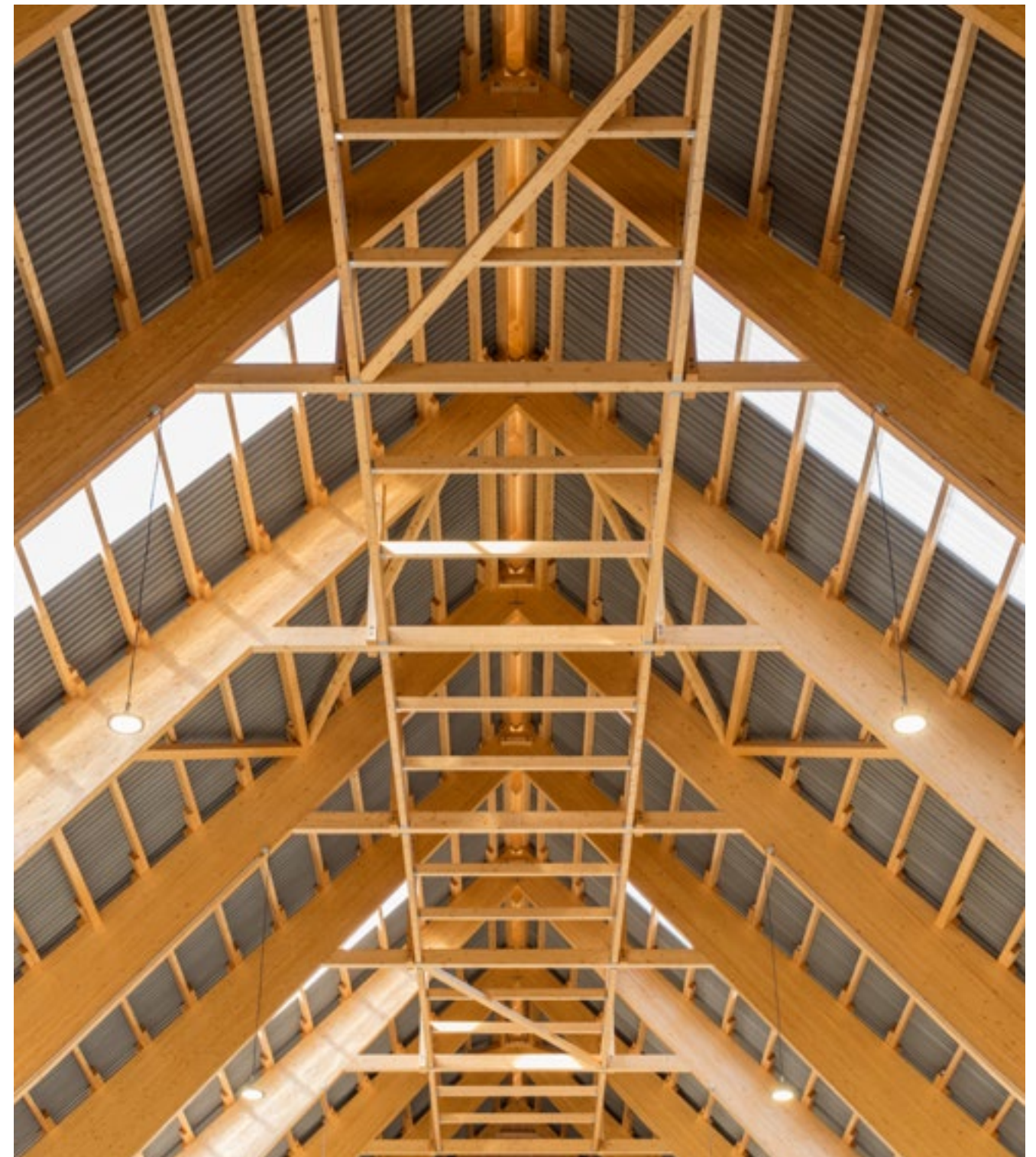
It is possible to design the purlins to suit a variety of applications: single-span, multiple-span, continuous, cantilevered or jointed purlins are all possible. Due to the efficient moment distribution, multiple-span purlins provide the most cost-effective solution. Care needs to be exercised with such a solution as the most effective placement for the purlins on top of the primary elements, leads to a greater structural depth.

Where building projects demand a double-span solution, it is recommended to design using a multiple-span purlin in order that the stress-concentration can be optimised. This is also true for situations where glulam purlins are used in combination with trapezoidal steel trusses, where the trusses span in longitudinal direction.

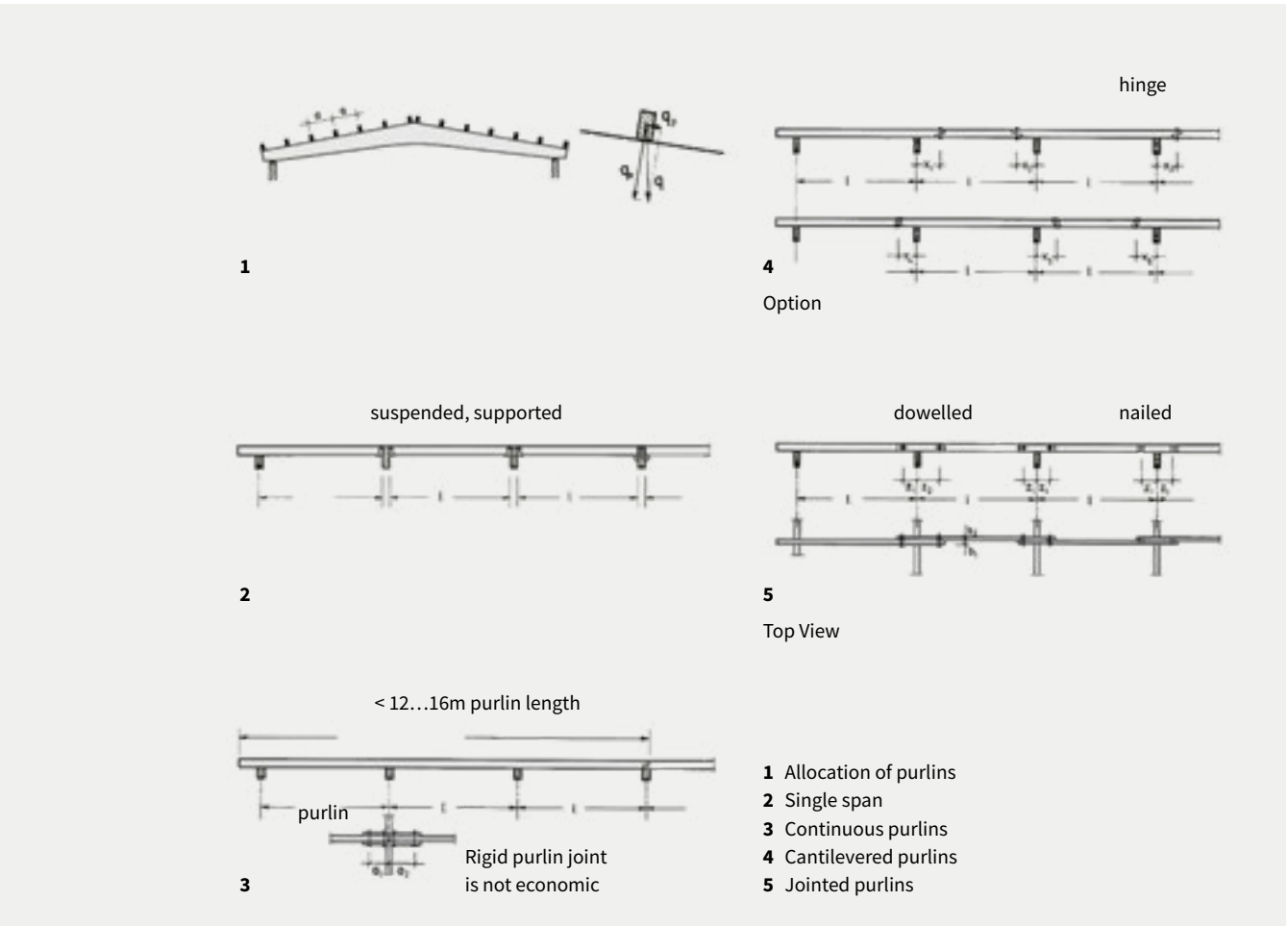
With increased roof pitches, purlins are manufactured to match the roof pitch or they are engineered to run perpendicular between the primary beams as single-spanning members. In this case the purlins shall be shaped to suit the roof pitch. This information should be written within the project specification.

In applications where the purlins are considered as single spanning members, the glulam shall be connected to the primary structure utilising proprietary steel connections. These connections, like all others when designing in glulam, shall be properly analysed by the structural engineer to ensure structural integrity and specified accordingly.

Where aesthetic considerations assume less significance the application of unplanned square timber as joint timber purlins may be considered as a cost saving. Although these may be relatively inexpensive, the distance between successive purlins tends to be limited through material section properties and therefore the roof structure is more functional rather than aesthetic. For this reason, joint purlins feature in combination with sheet roofing materials i.e. fibre reinforced cement boards which are used primarily for agricultural applications. Where composite roofing panels are to be specified, glulam sections provide a more attractive solution. The material section properties allow bigger spans at the correct centres ensuring proper support for the roofing.



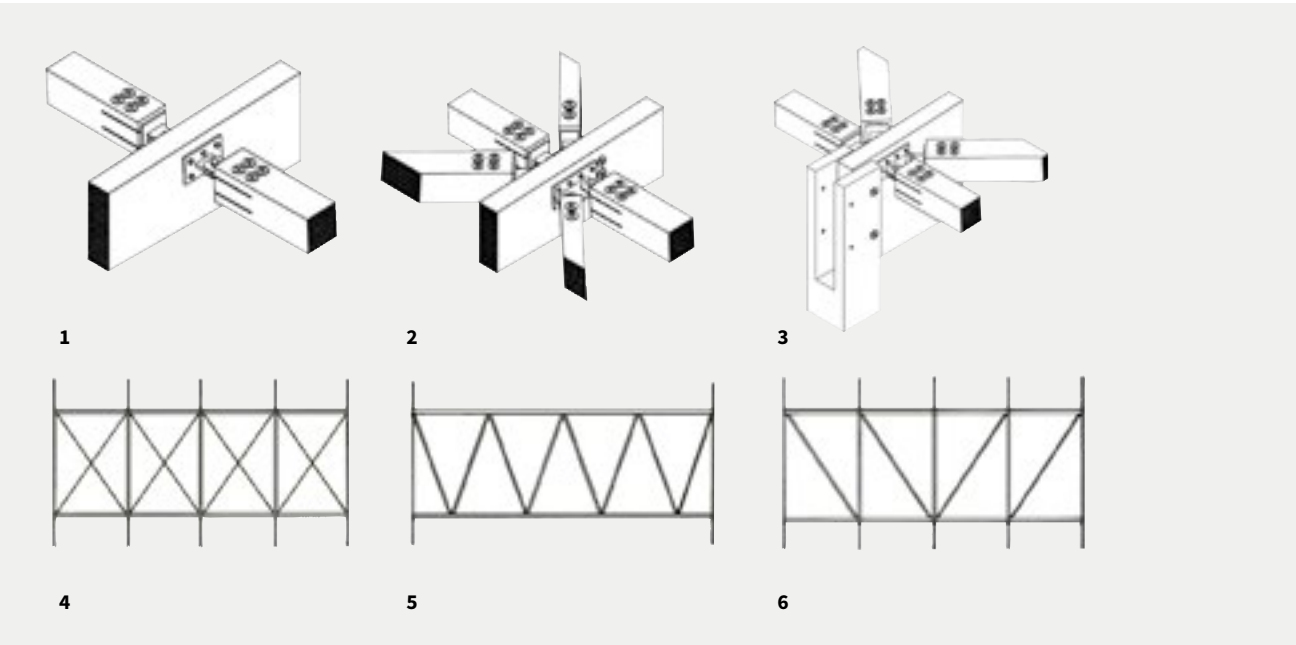
Purlins



Stiffening / Bracing

As part of the overall structural design and the ultimate building performance for free-span structures, the overturning forces have to be transferred by bracing or rigid shear panels to the foundations ensuring building stiffness. The detailed design of the bracing system should be determined by the overall building structural engineer. Often the bracing members – constructed in either timber or steel – are designed to ensure the loads are transferred towards the gable walls of the building. Where this is the case, the gable columns should be designed as pin-ended so that they can be dismantled and relocated easily, should the building need to be extended. The bracing members should be designed to accommodate the compressive forces as well as the tensile stressing. Glulam bracing members are economic and the fire resistance grades R 30 and R 60 can be easily achieved.

Where the roofing structure is intended to brace the structure special care should be taken during the construction phase ensuring adequate fixings are provided as well as temporary propping until the structure is complete. Where the bracing elements are part of a “closed” roofing system they are only constrained by overturning forces, and in this case it should not be necessary to transfer the loads into the building foundations.



- 1 Connection for compression-and tensile stressing
- 2 Nodal point
- 3 Connection of bearing for the beams
- 4 Intersected diagonals (tensile stressing only)
- 5 Rising and falling diagonals
- 6 Falling diagonals

Considerations for column design

When designing structural columns we have to differentiate between structures with rigid, fixed-end columns and those with pin-ended columns. A structure with pin-ended columns usually results in a relatively simple foundation solution. The overall bracing of the structure is often realized using wall- and roof panels. It is considered as a standard for a minimum of one column to be rigidly fixed to the foundation per building axis.

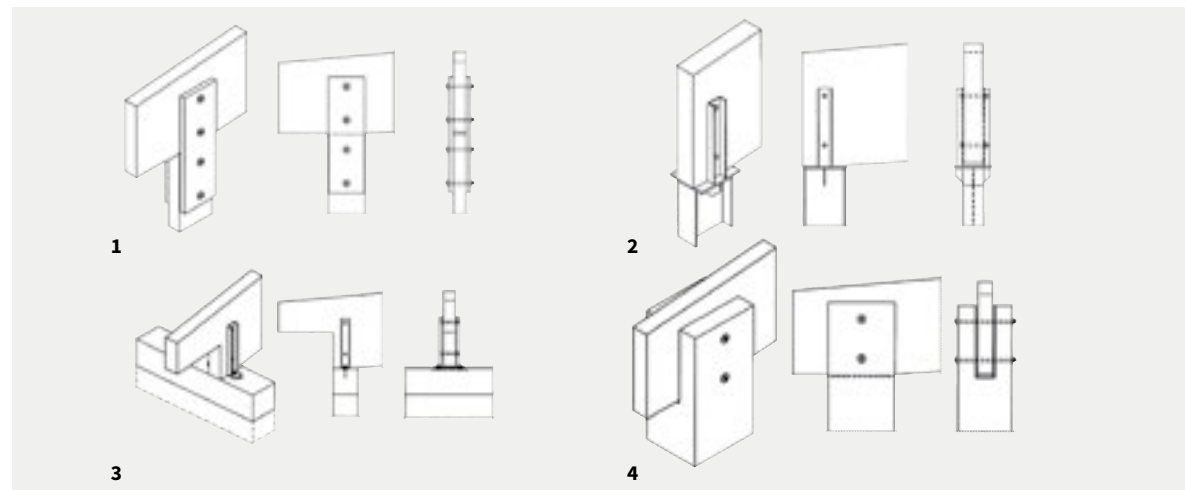
In order to transfer the vertical stresses from the roof and the climatic loads towards the foundations, timber, steel or reinforced concrete columns are utilised. The decision on which material is best suited for this application is often determined on the designated fire performance requirements rather than economics. Where demanded, a fire-resistance of R 90 can be easily realised with reinforced concrete columns, however without a secondary treatment steel columns have minimal fire-resistance. Structural steelwork loses its ability to carry load when exposed to temperatures beyond 500 degrees. The steel yields and its plasticity results in structural failure. The advantage that steel columns over concrete have is their relative small section size where plan space is a constraint. In addition, the thermal characteristics of both ma-

terials, needs to be considered when detailing the external envelope. Both easily conduct heat and so thermal bridging must be accounted for during the design and installation of the envelope materials. With both concrete and steel columns secondary support for internal fixtures and fittings can be easily accommodated. The illustrations show a variety of options for column head design and arrangements.

In general, the forked bearing detail should equate to two thirds the height of the beam. During the building planning process it should be kept in mind that there is a need for sufficient bearing areas ensuring they can transfer the loads into the load bearing element. The following formula provides a rule for basic indication which may help to determine the necessary bearing area:

$$l_{\text{Bearing}} [\text{cm}] = l_{\text{Beam}} [\text{m}]$$

In order to avoid the formation of cracks, it is imperative that the natural swelling and shrinking process of the glulam member is not disturbed. It is recommended therefore to implement the upper drillings required for the connections as elongated holes during manufacture.



1 Timber column
2 Steel column
3 concrete ring beam
4 forked concrete column



How you can benefit from our know-how

As an organisation, we are recognised in glulam construction and can provide over 80 years of experience within the timber industry. Our know how and experience allows us to develop all kinds of building project solutions irrespective of location. Whether national or international, regardless of complexity, we are always willing to deliver the correct engineered solution.

Glulam (glue laminated timber), a high-tech and truly sustainable construction material, shall become the building material of choice in the future. We are at the forefront of technological development and advancement. Our continual commitment and company ethos ensures we remain market leaders.

Regarding all technical questions, queries or advice, please do not hesitate to contact us, and our highly qualified team of professionals will be delighted to provide you with detailed technical information and share their extensive knowledge.



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