GLULAM BEAMS

L1 masterline

Facts on glulam beams:

Types of wood
- Spruce
- Larch

Surface qualities
- Visible quality (Si)
- Industrial quality (NSi)

Dimensions
- Widths: 6 to 28 cm
- Heights: 10 to 220 cm
- Lengths: 3 to 36 m

Product standard
- EN 14080, DIN 1052/EN 386

Strength classes
- GL 24h
- GL 28c
- GL 32c
- GL 36c

Shapes
- Straight glulam
- Cambered glulam
- Curved glulam

Contents

Glulam – timber construction in a new dimension

L1 masterline is the quality label for glulam beams from the Mayr-Melnhof Kaufmann Group.

The L1 masterline trademark stands for innovative engineering, superb quality, expert advice and dependable delivery service.

As an internationally oriented company, we advise architects, engineers, timber builders and commercial customers throughout the world in the planning and realisation of challenging, creative building projects with our timber engineering products. We regard exceptional requirements as a challenge.

▲ *Japanese pavillion, Hannover, Germany*
▶ *Champagne and wine cellars, Mezzocorona/Italy*
▼ *Exhibition halls, Friedrichshafen/Germany*

At a glance

- Large spans
- Free shapes
- Load-bearing and lightweight
- Dry construction
- Easy to machine
- High resistance to fire
- Chemical resistance
- Natural building material
- Excellent thermal insulation
- Comfortable ambient conditions
- Recyclable building material
- CO_2 reservoir – climate-friendly

Numerous areas of use

- Residential houses and apartment buildings
- Industrial buildings and warehouses
- Office and administration buildings
- Exhibition halls
- Composting and bulk material halls
- Nurseries and schools
- Sports halls and swimming pools
- Hotel and restaurant buildings
- Churches and holy buildings
- Bridge support structures
- Trade fair and exhibition constructions

Aesthetic, resilient and incredibly versatile

The trend in recent years towards «green» construction has induced architects and engineers to use timber – the natural building material – as the most salient architectural element in a very wide range of building projects.

The fascination of glulam lies in the flexibility of the timber to be formed into almost any shape while maintaining its high load-bearing capacity. The elements made of planed, parallel-glued boards are distinguished by outstanding dimensional stability, efficiency and versatility. The combination of straight, curved and three-dimensional constructional elements allows architects virtually unlimited freedom of design.

EG-conformity certificate
EN 14080

Certificate of compliance
DIN 1052

PEFC
Chain of Custody

ISO 9001
Quality management

Large spans

For the same load-bearing capacity glulam is lighter than steel.

The high load-bearing capacity with lower dead weight allows tight dimensioning of the components.

Thanks to the excellent material properties spans of up to 100 metres can be realised using the proper structural system and strength graded glulam.

Even with regard to transport timber offers significant advantages because of its low dead weight. The costs of transport and the environmental pollution are comparatively low.

Free shapes

Glulam can be produced as straight, pre-cambered, arched or bent members in a great variety of cross-sections.

The high load-bearing capacity allows narrow, elegant dimensions of the glued laminated beams. The tremendous dimensional stability makes a fascinating range of shapes possible.

Architects, planners and clients have a nice choice of forms due to the flexibility of designs.

◄ *Theatrum Anatomicum, Bregenz, Austria*

High resistance to fire

A supporting structure made of glulam is much safer than an unprotected steel construction in the event of fire. In any blaze a flame barrier forms around the load-bearing core that reduces the ingress of oxygen and heat from the outside, thereby significantly delaying any further combustion.

In contrast to other building materials such as steel, the burning properties of glulam are predictable. A fire resistance of 30 minutes is easily achieved. With appropriate cross sections even 60 minutes or more are possible.

Expensive fire protection coatings are usually not required.

Resistant to aggressive chemical substances

Glulam is resistant to aggressive chemical substances.

Therefore structures made of glulam are also suitable for buildings which are used to store materials such as fertilisers, salt or acids.

Glulam beams and trusses are the preferred building material when it comes to swimming pool and wellness spa structures as they combine structural advantages with the resistant to an aggressive climate while providing an aesthetical appearance.

▶ *Covered swimming pool, Yerukim*

Durable comfort

L1 masterline lends to a warm, comfortable ambience which immediately gives people a sense of well being.

The use of glulam promotes healthy ambient conditions.

Glulam beams are natural, durable and aesthetic.

The percieved surface temperature of wood lies significantly above other building materials. Even at lower room temperatures this leads to a comfortable room climate.

▶ *Administration of Mayr-Melnhof Kaufmann, St.Georgen, Austria*

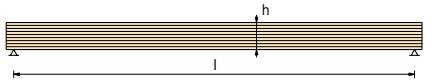
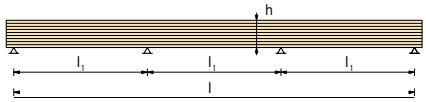
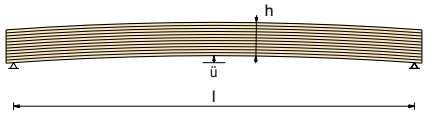
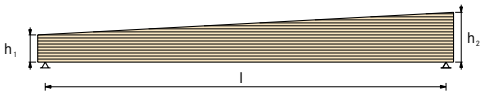
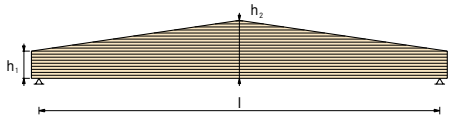
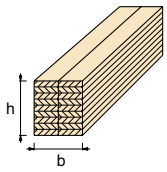
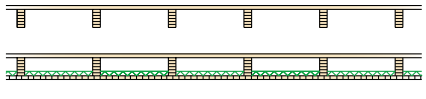
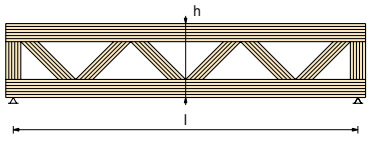
Climate protection and sustainability

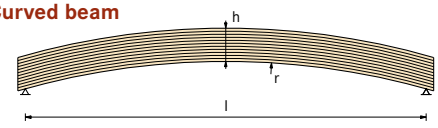
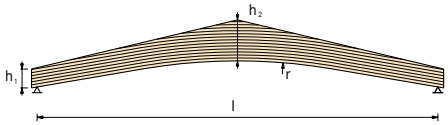
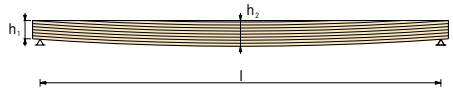
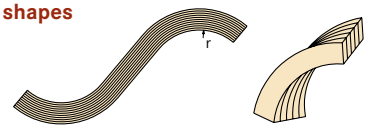
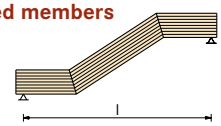
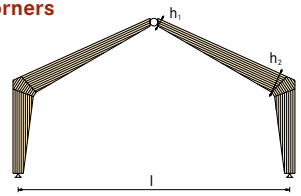
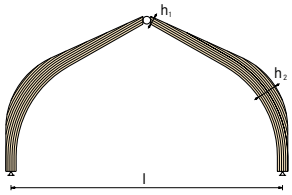
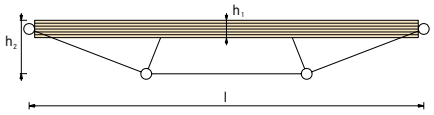
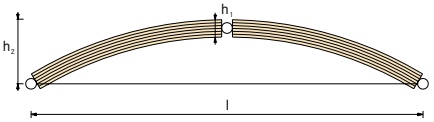
The raw material used in the production of our glulam originates predominantly from the domestic forests of Austria, Switzerland and Germany.

For generations these forests have been managed and tended according to the simple principle of sustainability: more trees are replanted than are harvested.
Timber is an excellent storage medium for the harmful greenhouse gas, carbon dioxide. Every cubic metre of timber used in construction reduces emissions of CO_2 into the atmosphere by an average of 2 tons.

L1 masterline products made from spruce are 100% PEFC certified.

STRUCTURAL SYSTEMS

Structural systems	Spans (m)	Width (cm)	Height (cm)	Spacing (m)
Parallel beam/Single span 	3-36	6-28	12-230 h = l / 16 bis l / 20	1-8
Parallel beam/Multiple spans 	3-36	6-28	12-230 h = l_1 / 20	1-8
Parallel beam with structural camber 	10-36	6-28	40-230 h = l / 16 bis l / 20	4-8
Single tapered beam 	10-36	10-28	h_1 = l / 30 h_2 = max 200 cm	2-6
Double tapered beam with straight lower chord 	10-36	10-28	h_2 = l / 16 h_1 = l / 35	4-8
Block gluing 	3-33	> 28	20-200	4-8
Ribbed and box elements 	5-20	100-200	20-60	–
Framework trusses 	20-60	12-28	100-500 h = l / 9	10-20

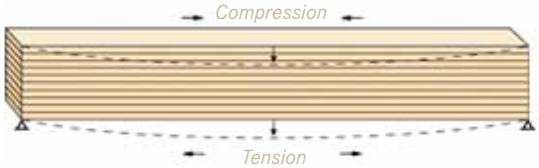
Structural systems	Spans (m)	Width (cm)	Height (cm)	Spacing (m)	Roof pitch (°)
Curved beam 	5-33	8-28	r ≥ 8 m d* = 40 mm r < 8 m d* = r / 200	2-6	Note transport height and width
Double tapered beam with curved lower chord 	10-33	10-28	h1 = l / 24 bis l / 32 h2 = l / 16 r ≥ 8 m d*=40mm r < 8 m d* = r/200	4-8	1-20° Note transport height and width
Fish-bellied beam 	20-33	10-28	h1 = l / 30 h2 = l / 16	4-8	–
Free shapes 	5-33	8-28	r ≥ 8 m d* = 40 mm r < 8 m d* = r / 200	–	–
Finger-jointed members 	10-40	8-28	12-230 h = l / 16 bis l / 20	–	–
Three-hinged system with fingerjointed frame corners 	15-40	12-28	12-28 h1 = l / 50 h2 = l / 18	5-10	10-60°
Three-hinged system with curved frame corners 	15-50	12-28	12-28 h1 = l / 50 h2 = l / 18	5-10	10-60°
Trussed systems with straight beam 	40-60	10-28	h1 = l / 30 bis l / 40 h2 = l / 10 Steel or timber suspension	10-20	–
Three-hinged frame with tension chord 	20-100	10-28	h1 = l / 40 h2 > l / 7 Steel or timber suspension	10-20	15-45°

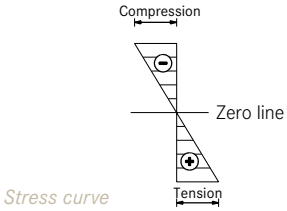
d = thickness of lamellas

Glulam

L1 masterline consists of at least 3 lamellas glued together with the grain of the lamellas longitudinally parallel. Glulam is normally stressed in bending, so that the highest stresses arise in the tensile and compression zone. The layered construction of glulam allows lamellas to be used in the various elastomechanical zones of the beam according to their quality (strength sorting). Thus the high-quality lamellas of a bending beam are laid across the beam height in the tensile and compression zone according to the stress curve. The middle layers can have a lower lamella strength.

Example of a bending member:



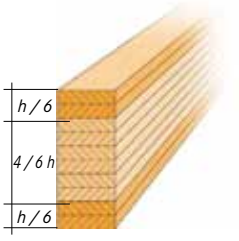


Types of wood

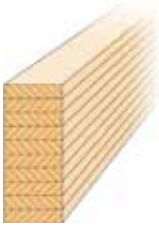
Spruce (Picea abies) / Fir (Abies alba) from domestic forests
Siberian Larch available in our stock beam delivery program, domestic Larch upon request

Lay-up

c = combined symmetrical
(L1 masterline standard)



h = homogeneous
(upon request only)



Strength classes

Standard	Strength class	Lay-up	Availability from Reuthe	Availability from Gaishorn	Availability from Richen
EN 14080 or DIN 1052-2008	GL 24	c		✓	
		h	✓	✓	✓
	GL 28	c	✓	✓	✓
		h			
	GL 32	c	✓	✓	
		h			
	GL 36	c		✓	
		h			

Gluing

Melamine resin-based adhesive, Adhesive Type I in acc. with EN 301, approved for gluing load-bearing timber components both for interiors and exteriors.

Colour of glued joints

Light-coloured glue lines (melamine adhesive)
Dark-coloured glue lines for custom glueing

Lamella thicknesses

The lamella thickness depends on the curvature of the component (radius) as well as the climatological conditions.

- Straight components: Lamella thickness d = 40 mm (applies to Service Classes 1 and 2 only)
- Curved components: Lamella thickness d = r/200
- For extreme climate conditions, for example direct exposure to the weather or sunlight as well as high demands due to the type of use (bakeries, car wash facilities or composting halls), smaller lamella thicknesses should be selected.

Moisture content

10 - 12 % (+ / - 2 %) on delivery

Density

Approx. 450 kg / m³

Thermal conductivity

λ = 0,13 W / (mK) parallel to the glue lines
λ = 0,15 W / (mK) vertical to the glue lines

Diffusion resistance

μ = 20 - 40

Emissions

Class E1

L1 masterline clearly falls below the limit values of emission class E1 (≤ 0.1 ppm HCHO).

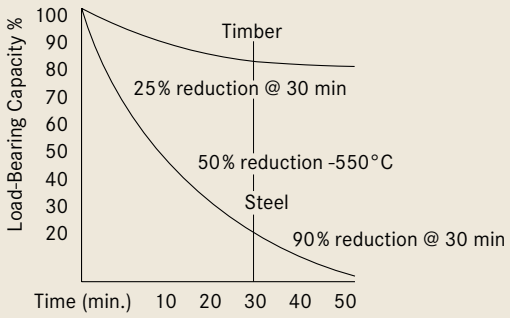
Reaction to fire

Glulam Classification:

Acc. to EN 13501:

European Class	D
Smoke Class	s2
Drop Class	d0

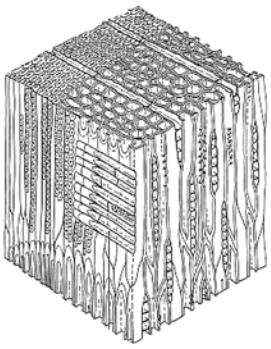
Acc. to DIN 4102-1:
B2 (standard inflammable)



Fire resistance

Charring rate 0,7 mm / min

Shrinkage and swelling behaviour



Cell structure of softwoods

Timber is a natural building material. It can both absorb and release moisture. The equilibrium moisture content of the component depends on the climatic conditions of the environment. To avoid changes in the member dimension, the timber moisture content should be matched at the intended installation site.

Glulam is produced with a timber moisture content of approx. 10 - 12 %. This corresponds to the equilibrium moisture content at a room temperature of 20 °C and a relative humidity of 65 %.

Glulam has an average shrinkage and swelling dimension in height and width of $\alpha_{u\perp}$ = 0,24 % per 1 % change in timber moisture content (Δu). Changes in length of $\alpha_{u\parallel}$ = 0,01 % can generally be ignored.

$\Delta h = \Delta u \times 0{,}24 / 100 \times h$ $\Delta b = \Delta u \times 0{,}24 / 100 \times b$ $\Delta l = \Delta u \times 0{,}01 / 100 \times l$

Optical quality

L1 masterline glulam is produced in two different surface qualities:

Visible quality: For visible use
e.g. in residential areas, nurseries, schools, sports facilities

Industrial quality: For use in non-visible areas
e.g. industrial buildings, composting plants, agricultural buildings, wood covered ceilings and roof beams

Planing

4 sides clean planed

Surface

Without impregnation

Edges

4 edges are slightly chamfered
Special shapes: other edge designs on request

Quality criteria

Surface quality of L1 masterline glulam:

Criteria	Visible quality (Si)	Industrial quality (NSi):
Planed quality	Roughness not permissible	Roughness permissible
	Planing marks permissible to a depth of 1 mm	Planing marks on knots permissible
Knots	Firmly intergrown knots permissible	Firmly intergrown knots permissible
	Knot holes permissible under certain conditions ø ≤ 20 mm permissible ø > 20 mm to be closed with round plugs or «boat plugs»	Knot holes permissible
Resin pockets	Sizes up to 5 x 50 mm permissible	Permissible
Pith	Permissible	Permissible
Insect infestation	Insect holes up to 2 mm are permissible	Insect tracks up to 2 mm are permissible
Discolourations	Blue stain and red streak up to 5 % of the visible surface permissible	Permissible
	Brown nail-resistant streaks not permissble	Brown nail-resistant streaks permissible
Shrinkage cracks	Up to 4 mm in width permissible	Without restriction

Notes

- Criteria are based on the surface quality at the time of delivery
- Proper material storage and assembly of the glulam after delivery must be ensured by the customer
- Because timber is a natural building material, material-related variations of the above-mentioned criteria are possible depending on the climatic conditions

Industrial surface quality

Visual surface quality

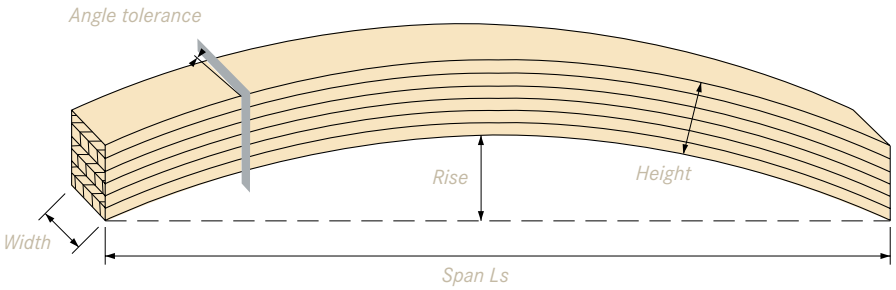
Dimensional tolerances for straight components

Our engineered timber products are always produced to the precise dimension ordered. However, because of machine tolerances and the natural behaviour of timber, there may be minor deviations which mean specific dimensional tolerances must be taken into account.

The dimensional tolerances for glulam are governed by EN 390.
The reference moisture content is 12%:

Cross-section width	50 mm ≤ b ≤ 300 mm		
Width tolerances	+ / - 2 mm		
Cross-section height	100 mm ≤ h ≤ 400 mm	400 mm < h ≤ 2500 mm	
Height tolerance	+ 4 mm / - 2 mm	+ 1 % / -0,5 %	
Beam lengths	< 2,0 m	2,0 m to < 20 m	> 20 m
Length tolerance	+ / - 2 mm	+ / - 0,1 %	+ / - 20 mm

Dimensional tolerances for curved components



Arched component	Without CNC machining	With CNC machining
Angle	Max. deviation 4 % of width	To exact dimension
Width and height	Max. deviation 1 %	To exact dimension
Deviation of rise	Up to +/-2 mm per metre arched length	To exact dimension

Note
When CNC special joinery is involved in the manufacture of curved components the glulam blank is produced with a surplus and then cut to the exact size on the CNC custom joinery machine. This means we are able to guarantee the absolute dimensional accuracy of the individual curve and each piece within a series of components ordered with CNC custom joinery.

Crack formation

As a result of the natural tendency of the wood to shrink and swell, shrinkage cracks may occur depending on the ambient conditions. The outer layers of the component can absorb moisture especially during the construction phase. To avoid shrinkage cracks, this timber moisture content must be gradually converted to the equilibrium moisture content through appropriate ventilation and careful heating of the building.

Shrinkage cracks may appear on the surfaces of the glulam components, even along the glue lines. Such shrinkage cracks may be tolerated up to a depth of 1/6 of the beam width (per side) in members without system-relevant transverse tensile stress.

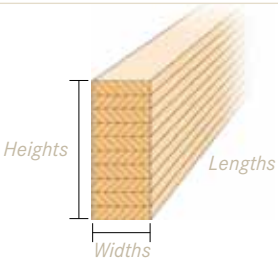
The tendency to crack formation increases with direct exposure to the weather and frequently changing climatic conditions.

RANGE OF PRODUCTS
STRAIGHT BEAMS

Glulam dimensions

Straight glulam beams	Spruce	Larch
Widths	from 6 to 28 cm	from 10 to 20 cm
Heights	from 10 to 220 cm	from 10 to 220 cm
Lengths	from 3 to 36 m	from 3 to 36 m

Other dimensions on request



Stock beams

12,0/13,0/13,5 or 16,0 m lengths are produced with a few «cm» of overlength. Precision end cuts upon request.

Custom cut lists

Order-based timber lists that are either delivered in multiple lengths or individually cut.

Multiple lengths

Individual lengths (commissions) are generally produced and delivered in multiple lengths with an additional allowance of 1 cm per individual length. In this case the multiple length is limited to either the transport length (12,0 or 13,5 m) or the length of the longest piece within the custom cut list.

Fixed lengths

Precision double end trim of individual beams with a tolerance of ± 2 mm

Standard cross-sections

Standard cross-sections are glulam cross-sections made of spruce/fir available in visible quality and Strength Class GL 24h and manufactured with lamella thicknesses of 40 mm.

Special cross-sections

Special cross-sections can be produced from standard cross-sections. Here the standard cross-section is planed to the special dimension, e.g. a delivery size of 15 x 30 cm originates from the standard size of 16 x 32 cm. Standard cross-sections usually cost less and are more readily available than special cross-sections.

Stock beams

Stock beams are standard cross-sections in lengths of 12,0 or 13,5 m kept in stock. Stocked goods are available at short notice.
The following table shows a selection of the typical standard or stock beams:

Height (cm) \ Width (cm)	6	8	10	12	14	16	18	20	24
10			10 x 10						
12	6 x 12	8 x 12	10 x 12	12 x 12					
14	6 x 14	8 x 14	10 x 14	12 x 14	14 x 14				
16	6 x 16	8 x 16	10 x 16	12 x 16	14 x 16	16 x 16			
18			10 x 18	12 x 18			18 x 18		
20	6 x 20	8 x 20	10 x 20	12 x 20	14 x 20	16 x 20		20 x 20	
24			10 x 24	12 x 24	14 x 24	16 x 24	18 x 24	20 x 24	24 x 24
28				12 x 28	14 x 28	16 x 28	18 x 28	20 x 28	
32					14 x 32	16 x 32	18 x 32	20 x 32	
36						16 x 36	18 x 36	20 x 36	
40						16 x 40		20 x 40	

Detailed stock cross-section lists can be obtained at **www.mm-kaufmann.com** or from your local customer representative.

Packaging

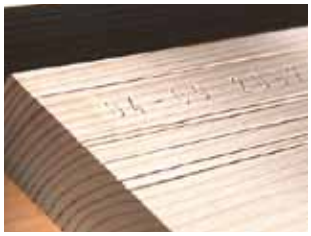
Stock beams:	Individually wrapped in plastic foil
Custom cut lists:	Bundle wrapped in plastic foil
Custom cut lists from stock beams:	Bundle or individually wrapped in plastic foil
Special components:	According to the size of the component and transportation method

The plastic wrapping:

- Provides transport protection against dirt and spray water
- Only provides limited protection of the component against UV radiation and water absorption
- Is not suitable for storing the glulam for longer periods

Short-term ingress of water does not indicate a deficiency. Please check the package on delivery for signs of water damage. If moisture or water has entered the package, cut off the film and quickly remove to ensure good circulation around the wet component.

Product identification



L1 masterline glulam is individually identified by embossing of the separate lamellas or UV marking with fluorescent lettering. The product is identified with the following information:

- Name of the factory
- Strength of the lamella
- Date of manufacture

This unique identification and traceability of the component provides builders, customers and suppliers with the assurance and certainty of the origin.

Labelling of the packages

Packages with L1 masterline glulam beams are provided with a package sticker that is easy to see on the outside. This easy-to-read package label includes the following information:

1. Customer name and address or delivery address
2. Order number and commission name where applicable
3. Delivery date (from order confirmation)
4. Numbering of the packages within an order
5. Details of strength or surface
6. Package contents: Number of items, cross-sections, lengths and cubature
7. First 2 digits of the postal code (delivery address)

Transport

Glulam components should only be transported by experienced and specifically equipped haulage companies.

Transport by lorry

Components with a maximum length of 13,60 m can be transported in open or closed lorries without any problems. The lorries are loaded in our factories with a side loading fork lift. If unloading by crane is required, this should be agreed in advance with our sales or logistical department.

Direct deliveries to a construction site are only possible following agreement with our logistics representative. Attention should be paid here to:

- Heavy goods transport requires accessible roads
- Clarification of unloading by crane or fork lift
- Fixed dates are only possible after return confirmation because of distances and road conditions

Special transport

Due to national and international traffic rules and regulations, components that exceed 13,60 m in length, 2,40 m in width or 2,60 m in height require special transportation that is subject to approval.

Our sales and logistics representative are experienced in this sector and always endeavour to find the optimum solution. In order to quote the exact beam dimensions are required.

Special transportation must be requested on an individual basis and requires a longer lead-time in the quotation phase than standard transport.

Containers

For shipment by sea, so-called BOX or Open Top (OT) containers in 20 ft (approx. 6 m) or 40 ft (approx. 12 m) lengths are used.

BOX containers are more difficult to load/unload than Open Top containers but are more easily available and more economic to transport.

Components > 12 m in length can be shipped by conventional means (breakbulk).

Rail

Depending on the destination and factory, transport by rail freight may be an economic alternative.

Our factories in Gaishorn and Kalwang have a rail connection.
Three types of rail carriage can be selected based on the component dimensions and availability:

- 2-axle rail carriage (Ks, Kbs) max. length 12,5 m, max. weight 25 ton
- 4-axle rail carriage (RS, Rgs) max. length 18,5 m, max. weight 50 ton
- 4-axle rail carriage (Rns-z) max. length 21 m, max. weight 50 ton

Product quality

Load-bearing glulam members are engineered, high-quality structural elements made of specially selected timber. Glulam may only be produced by companies that have appropriate certification of suitability for the gluing of load-bearing timber components.

The safety and quality of the product in the Mayr-Melnhof Kaufmann Group factories are guaranteed by the following measures:

- Continuous testing and monitoring of ongoing production
- Regular external monitoring by independent testing institutes (MPA Stuttgart, TU Munich, HFA Vienna, etc.)
- Quality management and full documentation of the manufacturing process

Certificates

Proof of suitability for the manufacture of load-bearing timber components is documented by corresponding certificates issued by the national and international monitoring institutes:

EG certificate of conformity

CE

Gaishorn
1359-CPD-0150

Kalwang
1359-CPD-0093

Reuthe
1359-CPD-0056

Richen
1359-CPD-0144

Certificate of compliance

Ü

Gaishorn, *ÜZ-BWU 03- I 14.21.126, TU Stuttgart*

Kalwang, *ÜZ-BWU 03- I 14.21.119, TU Stuttgart*

Reuthe, *ÜZ-BWU 03- I 14.21.115, TU Stuttgart*

Richen, *05/34, TU Munich*

Environment

PEFC

Quality management

TÜV CERT

PEFC Group certificate
HCA-CoC-0120

Reuthe, *ISO 9001*
No. 20 100 52000864

A full list of all currently valid certificates can be found at **www.mm-kaufmann.com**

Precambered beams

In some cases glulam with a camber may be called for. Attention must be paid here to the following points:

- Manufacturing requires a special press setting or the use of a template.
- Reasonable cambers are limited to l/200 or l/300, i.e. approx. 4 to 15 cm.
- Please clarify technical feasibility beforehand with your customer representative.

Curved beams

L1 masterline glulam components can be produced in single or double-curved shapes. Depending on the production site, the following guidelines apply:

- The curved shape can be freely selected (single, double or elliptical curves).
- Reuthe factory: Radii from 1 m to L = 33 m, Gaishorn factory from 3 m radius to L = 22 m
- The lamella thickness is determined by the smallest radius of the curve.
- Exact CNC shape milling possible, dimensional accuracy +/- 0,5 mm
- Transport restrictions must be considered: The maximum rise of a component is 4,0 m.

Block gluing

Glulam widths > 28 cm require block gluing. In such cases two or more cross-sections can be glued together in a structurally effective way. The manufacture of the block gluing is governed by DIN 1052 and executed in our Reuthe factory:

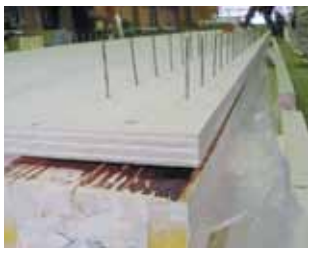
- The manufacturing process is subject to a supervision contract.
- Gluing takes place with a joint-filling glue up to a joint thickness of 2 mm.
- A dark-coloured phenol-resorcin resin glue is generally used.
- When dark-coloured PRF glue is used, the glue line remains visible.
- Block-glued components may only be used in service class 1 and 2.

Finger-jointed members

Individual rectangular-shaped components can become structurally and effectively joined with a universal fingerjoint to an angled load-bearing shape.

- Proven manufacturing process for the redirection of forces, for example in frames
- Higher safety margin than mechanical joints
- Uniform shrinkage and swelling behaviour of the two components
- For manufacturing process, glued joint and service class, see chapter on «Block gluing»

Glued and screwed connections



Glulam beams and engineered wood panels are joined to become load-bearing and rigid using threaded pressure gluing to produce high-performance ribbed and box elements.

- Large spans with less material through the use of cassette elements
- Underside view flush with the ceiling with engineered wood panel (e.g. K1 multiplan) without exposing the load bearing structure
- Service installations can be integrated in detailed preliminary planning
- Flat plane support structures with factory-produced primary waterproof layer are possible
- For manufacturing process, glued joint and service class, see chapter on «Block gluing»

Additional services

Mayr-Melnhof Kaufmann provides a wide range of services and custom joinery. These may be very different in nature from factory to factory due to the available production systems. This table shows the range of services provided by the four sites.

Services at the site	Reuthe	Gaishorn / Kalwang	Richen
Straight components	b = 6 - 28 cm h = 10 - 220 cm l = from 3 - 32,5 m	b = 6 - 26 cm h = 10 - 220 cm l = from 3 - 36 m	b = 6 - 24 cm h = 10 - 88 cm l = from 3 - 24 m
Cambered components	l / 200 or l / 300	On request	–
Curved components	Starting from 1 m radius to 33 m length	Starting from 3 m radius to 22 m length	–
Special gluing	Block, universal fingerjointing and threaded pressure gluing	–	–
Impregnations	Primers, stains on request	Primers, stains on request	On request
Custom joinery, CNC machining	All custom joinery, element construction	Simple custom joinery	Simple custom joinery
Pre-assembly	Steel sections, connecting materials, elements	On request	On request

Technical consultation

Mayr-Melnhof Kaufmann provides valuable support and expert technical consultation. The following services can also be offered from our technical office if required:

- Preliminary dimensioning
- Structural / engineering calculation
- Shop drawings

Chemical surface protection

Our glulam is generally supplied untreated. Regional building regulations or specific customer wishes may, however, necessitate chemical surface treatment. Here a difference is made between three product groups that are applied on a water-soluble basis with low VOC content using rolling, painting or spraying technology:

- Impregnation without biocides (weather and shipping protection)
- Impregnation with biocides, protection against fungus (P), blue stain (B) and insect prevention (Iv) or termite protection (IP)
- Coloured stains with high-quality surface coatings

Custom joinery

According to customer needs and project requirements L1 masterline glulam can be offered with precise custom joinery. Here a differentiation is made between traditional manual custom joinery and CNC machining.

Custom joinery categories

Simple custom joinery includes angular and diagonal cuts, trimmings and drilled holes. Complex custom joinery categories such as mitred joints, valleys, slots, angled and sloped cuts can, in most cases, be performed efficiently on our CNC custom joinery portals depending on the quantity and complexity.

CNC custom joinery provides you with quantifiable advantages:

- Precision custom joinery with maximum dimensional accuracy (+/-0,5 mm)
- Complex angle cuts, sloped cuts, arches, milling grooves and drilled holes
- Dimensional accuracy, especially within a series
- More efficient and cost-saving custom joinery

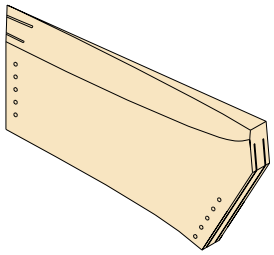
CNC machining centre – Reuthe

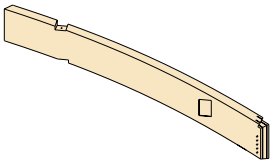
At the Reuthe facility Mayr-Melnhof Kaufmann has one of the most modern and highest performance CNC timber machining centres in Europe. Three CNC custom joinery portals are available that focus on different machining approaches that depend on requirements.

Components up to 36 m length

Large components, curves and box elements are machined with extremely high precision on the CNC-controlled, 5-axis custom joinery gantry.

- Components up to 36 m in length, 5,8 m in width and 1,25 m in height
- Straight and curved components, large format panels and box elements
- Fully-automatic tool change units

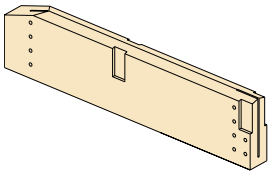


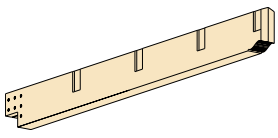


Straight beams up to 18 m length

Straight beams up to 18 m in length are machined on our 6-axis custom joinery portal:

- Straight components up to 18 m in length, max. cross-section 20/80 cm
- 6-sided machining, also face and longitudinal custom joinery
- Suitable for angled and sloped cuts, ridged profiles as well as slotting and drilling
- Fully-automatic tool change units





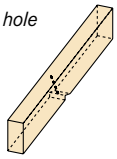
Traditional custom joinery

Typical, traditional engineered wood joints are machined on a third custom joinery gantry:

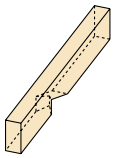
- Straight components up to 15 m in length, max. cross-section 30/62,5 cm
- 6-sided machining, both face and longitudinal custom joinery
- Suitable for end cuts, slots, drilled holes and edge cuts
- Up to 30 installed and fixed tools

CNC machining examples

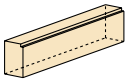
«Normal» birdsmouth notch
incl. 8 mm drilled hole for rafter nails



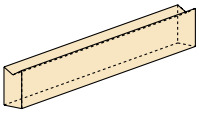
Valley rafter with notch



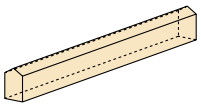
Rebate



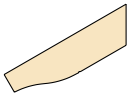
Valley



Hip

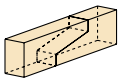


Moulded rafter head

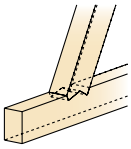


Diagonal cut

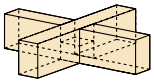
Scarf joint



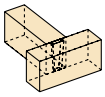
Double stepped joint



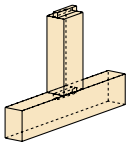
Cross halving



Dovetail joint



Mortise and tenon



File format for CNC machining

To ensure efficient and cost-effective CNC machining, it is beneficial to provide our technical office with your CNC data in one of the following formats:

- Cadwork 3D file with individual item drawing as a 2D file (*.3d and *.2d)
- Individual item drawing as a 2D file (*.2d), AutoCAD (*.dwg) or *.dxf file
- Hundegger file (*.bvn) with individual item drawing as an AutoCAD (*.dwg) or *.dxf file

Connection materials

Subject to agreement, commercially available connection materials from established manufacturers (joist hangers, brackets, purlin connectors, bolts, screws, etc.) can be supplied and pre-mounted.

Steel parts

Individually welded steel parts (slotted plates, hinges, bearing supports, etc.) can be supplied and pre-mounted based on the order.

Pre-assembly

On request we offer to assemble steel and connecting hardware for you at the Reuthe facility. Pre-assembly is more cost-effective than subsequent assembly on-site and simplifies the workflows.

Steel-timber joints

In modern timber construction various cost-efficient and high-performance jointing techniques are available. These include:

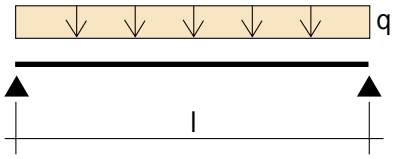
- Steel plate shaped sections
- Welded steel sections
- Special types of guide pins and dowels
- Self-drilling screws
- Screws and threated rods for lateral securing

Site assembly

Site assembly of the L1 masterline members is carried out by our customers in the timber construction industry or by construction companies who specialize in the assembly of timber structures. Mayr-Melnhof Kaufmann itself does not offer installation services. We would be glad to give you the names of experienced, skilled companies in your region on request.

Glulam span table for single span beams

These tables are only to be used for pre-dimensioning purposes. Prior to implementation a precise structural analysis must be carried out in accordance with the currently applicable dimensioning standards in every case.



System assumptions:

- Uniform loading
- Girder is supported against lateral shifting; no danger of tilting
- Uniform load q is composed of:
  g: permanent load, incl. dead load of the beam
  p: live load or snow load
- Shear and creep deformations are not taken into account

Material assumptions: GL 24h (BS 11)

Material properties for BS 11 acc. to DIN 1052-1988:

E = 11.000 [N / mm²] Modulus of elasticity
$\sigma_{b,zul}$ = 11 [N / mm²] Permissible bending stress
τ_{zul} = 1,2 [N / mm²] Permissible shear stress
f_{zul} = l / 300 [m] Permissible deformation

Leading design criteria:

Deflection Modulus Shear force

mm		Maximum permissible spans at widths 100 – 320 mm / q (kN / m)																			
b	h	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	15,0	20,0	25,0	30,0
80	100	2,66 f	2,32 f	2,11 f	1,96 f	1,84 f	1,75 f	1,67 f	1,61 f	1,53 M	1,40 M	1,29 M	1,21 M	1,14 M	1,08 M	1,03 M	0,99 M	0,85 Q	0,64 Q	0,51 Q	0,43 Q
100	100	2,86 f	2,50 f	2,27 f	2,11 f	1,99 f	1,89 f	1,80 f	1,73 f	1,67 f	1,56 M	1,45 M	1,35 M	1,28 M	1,21 M	1,15 M	1,11 M	0,99 M	0,80 Q	0,64 Q	0,53 Q
80	120	3,19 f	2,79 f	2,53 f	2,35 f	2,21 f	2,10 f	2,01 f	1,93 f	1,84 M	1,68 M	1,55 M	1,45 M	1,37 M	1,30 M	1,24 M	1,19 M	1,02 Q	0,77 Q	0,61 Q	0,51 Q
100	120	3,44 f	3,00 f	2,73 f	2,53 f	2,38 f	2,26 f	2,16 f	2,08 f	2,01 f	1,88 M	1,74 M	1,62 M	1,53 M	1,45 M	1,39 M	1,33 M	1,19 M	0,96 Q	0,77 Q	0,64 Q
120	120	3,65 f	3,19 f	2,90 f	2,69 f	2,53 f	2,40 f	2,30 f	2,21 f	2,14 f	2,01 f	1,90 M	1,78 M	1,68 M	1,59 M	1,52 M	1,45 M	1,30 M	1,13 M	0,92 Q	0,77 Q
80	160	4,25 f	3,71 f	3,38 f	3,13 f	2,95 f	2,80 f	2,68 f	2,58 f	2,45 M	2,24 M	2,07 M	1,94 M	1,83 M	1,73 M	1,65 M	1,58 M	1,37 Q	1,02 Q	0,82 Q	0,68 Q
100	160	4,58 f	4,00 f	3,64 f	3,38 f	3,18 f	3,02 f	2,89 f	2,77 f	2,68 f	2,50 M	2,32 M	2,17 M	2,04 M	1,94 M	1,85 M	1,77 M	1,58 M	1,28 Q	1,02 Q	0,85 Q
120	160	4,87 f	4,25 f	3,86 f	3,59 f	3,38 f	3,21 f	3,07 f	2,95 f	2,85 f	2,68 f	2,54 M	2,37 M	2,24 M	2,12 M	2,02 M	1,94 M	1,73 M	1,50 M	1,23 Q	1,02 Q
140	160	5,12 f	4,48 f	4,07 f	3,78 f	3,55 f	3,38 f	3,23 f	3,10 f	3,00 f	2,82 f	2,68 f	2,56 f	2,42 M	2,29 M	2,19 M	2,09 M	1,87 M	1,62 M	1,43 Q	1,19 Q
160	160	5,36 f	4,68 f	4,25 f	3,95 f	3,71 f	3,53 f	3,38 f	3,25 f	3,13 f	2,95 f	2,80 f	2,68 f	2,58 f	2,45 M	2,34 M	2,24 M	2,00 M	1,73 M	1,55 M	1,37 Q
100	200	5,73 f	5,00 f	4,54 f	4,22 f	3,97 f	3,77 f	3,61 f	3,47 f	3,35 f	3,13 M	2,89 M	2,71 M	2,55 M	2,42 M	2,31 M	2,21 M	1,98 M	1,60 Q	1,28 Q	1,07 Q
120	200	6,08 f	5,32 f	4,83 f	4,48 f	4,22 f	4,01 f	3,83 f	3,69 f	3,56 f	3,35 f	3,17 M	2,97 M	2,80 M	2,65 M	2,53 M	2,42 M	2,17 M	1,88 M	1,54 Q	1,28 Q
140	200	6,41 f	5,60 f	5,08 f	4,72 f	4,44 f	4,22 f	4,04 f	3,88 f	3,75 f	3,53 f	3,35 f	3,20 f	3,02 M	2,87 M	2,73 M	2,62 M	2,34 M	2,03 M	1,79 Q	1,49 Q
160	200	6,70 f	5,85 f	5,32 f	4,93 f	4,64 f	4,41 f	4,22 f	4,06 f	3,92 f	3,69 f	3,50 f	3,35 f	3,22 f	3,06 M	2,92 M	2,80 M	2,50 M	2,17 M	1,94 M	1,71 Q
180	200	6,97 f	6,08 f	5,53 f	5,13 f	4,83 f	4,59 f	4,39 f	4,22 f	4,07 f	3,83 f	3,64 f	3,48 f	3,35 f	3,23 f	3,10 M	2,97 M	2,65 M	2,30 M	2,06 M	1,88 M
200	200	7,21 f	6,30 f	5,73 f	5,32 f	5,00 f	4,75 f	4,54 f	4,37 f	4,22 f	3,97 f	3,77 f	3,61 f	3,47 f	3,35 f	3,24 f	3,13 M	2,80 M	2,42 M	2,17 M	1,98 M
100	240	6,87 f	6,00 f	5,45 f	5,06 f	4,76 f	4,53 f	4,33 f	4,16 f	4,02 f	3,75 M	3,47 M	3,25 M	3,06 M	2,91 M	2,77 M	2,65 M	2,37 M	1,92 Q	1,54 Q	1,28 Q
120	240	7,30 f	6,38 f	5,80 f	5,38 f	5,06 f	4,81 f	4,60 f	4,42 f	4,27 f	4,02 f	3,81 M	3,56 M	3,36 M	3,18 M	3,04 M	2,91 M	2,60 M	2,25 M	1,84 Q	1,54 Q
140	240	7,69 f	6,71 f	6,10 f	5,66 f	5,33 f	5,06 f	4,84 f	4,66 f	4,50 f	4,23 f	4,02 f	3,84 f	3,63 M	3,44 M	3,28 M	3,14 M	2,81 M	2,43 M	2,15 Q	1,79 Q
160	240	8,04 f	7,02 f	6,38 f	5,92 f	5,57 f	5,29 f	5,06 f	4,87 f	4,70 f	4,42 f	4,20 f	4,02 f	3,86 f	3,68 M	3,51 M	3,36 M	3,00 M	2,60 M	2,33 M	2,05 Q
180	240	8,36 f	7,30 f	6,63 f	6,16 f	5,80 f	5,51 f	5,27 f	5,06 f	4,89 f	4,60 f	4,37 f	4,18 f	4,02 f	3,88 f	3,72 M	3,56 M	3,18 M	2,76 M	2,47 M	2,25 M
200	240	8,66 f	7,56 f	6,87 f	6,38 f	6,00 f	5,70 f	5,45 f	5,24 f	5,06 f	4,76 f	4,53 f	4,33 f	4,16 f	4,02 f	3,89 f	3,75 M	3,36 M	2,91 M	2,60 M	2,37 M
240	240	9,20 f	8,04 f	7,30 f	6,78 f	6,38 f	6,06 f	5,80 f	5,57 f	5,38 f	5,06 f	4,81 f	4,60 f	4,42 f	4,27 f	4,14 f	4,02 f	3,68 M	3,18 M	2,85 M	2,60 M
100	280	8,02 f	7,00 f	6,36 f	5,91 f	5,56 f	5,28 f	5,05 f	4,86 f	4,69 f	4,38 M	4,05 M	3,79 M	3,57 M	3,39 M	3,23 M	3,10 M	2,77 M	2,24 Q	1,79 Q	1,49 Q
120	280	8,52 f	7,44 f	6,76 f	6,28 f	5,91 f	5,61 f	5,37 f	5,16 f	4,98 f	4,69 f	4,44 M	4,15 M	3,92 M	3,71 M	3,54 M	3,39 M	3,03 M	2,63 M	2,15 Q	1,79 Q
140	280	8,97 f	7,83 f	7,12 f	6,61 f	6,22 f	5,91 f	5,65 f	5,43 f	5,24 f	4,94 f	4,69 f	4,48 f	4,23 M	4,01 M	3,83 M	3,66 M	3,28 M	2,84 M	2,51 Q	2,09 Q
160	280	9,38 f	8,19 f	7,44 f	6,91 f	6,50 f	6,18 f	5,91 f	5,68 f	5,48 f	5,16 f	4,90 f	4,69 f	4,51 f	4,29 M	4,09 M	3,92 M	3,50 M	3,03 M	2,71 M	2,39 Q
180	280	9,75 f	8,52 f	7,74 f	7,18 f	6,76 f	6,42 f	6,14 f	5,91 f	5,70 f	5,37 f	5,10 f	4,88 f	4,69 f	4,53 f	4,34 M	4,15 M	3,71 M	3,22 M	2,88 M	2,63 M
200	280	10,10 f	8,82 f	8,02 f	7,44 f	7,00 f	6,65 f	6,36 f	6,12 f	5,91 f	5,56 f	5,28 f	5,05 f	4,86 f	4,69 f	4,54 f	4,38 M	3,92 M	3,39 M	3,03 M	2,77 M
240	280	10,73 f	9,38 f	8,52 f	7,91 f	7,44 f	7,07 f	6,76 f	6,50 f	6,28 f	5,91 f	5,61 f	5,37 f	5,16 f	4,98 f	4,83 f	4,69 f	4,29 M	3,71 M	3,32 M	3,03 M
120	320	9,74 f	8,50 f	7,73 f	7,17 f	6,75 f	6,41 f	6,13 f	5,90 f	5,69 f	5,36 f	5,07 M	4,75 M	4,47 M	4,25 M	4,05 M	3,88 M	3,47 M	3,00 M	2,46 Q	2,05 Q
140	320	10,25 f	8,95 f	8,13 f	7,55 f	7,11 f	6,75 f	6,46 f	6,21 f	5,99 f	5,64 f	5,36 f	5,12 f	4,83 M	4,59 M	4,37 M	4,19 M	3,74 M	3,24 M	2,87 Q	2,39 Q
160	320	10,72 f	9,36 f	8,50 f	7,90 f	7,43 f	7,06 f	6,75 f	6,49 f	6,27 f	5,90 f	5,60 f	5,36 f	5,15 f	4,90 M	4,67 M	4,47 M	4,00 M	3,47 M	3,10 M	2,73 Q
180	320	11,14 f	9,74 f	8,85 f	8,21 f	7,73 f	7,34 f	7,02 f	6,75 f	6,52 f	6,13 f	5,83 f	5,57 f	5,36 f	5,17 f	4,96 M	4,75 M	4,25 M	3,68 M	3,29 M	3,00 M
200	320	11,54 f	10,08 f	9,16 f	8,50 f	8,00 f	7,60 f	7,27 f	6,99 f	6,75 f	6,35 f	6,03 f	5,77 f	5,55 f	5,36 f	5,19 f	5,00 M	4,47 M	3,88 M	3,47 M	3,16 M
240	320	12,27 f	10,72 f	9,74 f	9,04 f	8,50 f	8,08 f	7,73 f	7,43 f	7,17 f	6,75 f	6,41 f	6,13 f	5,90 f	5,69 f	5,52 f	5,36 f	4,90 M	4,25 M	3,80 M	3,47 M

mm		Maximum permissible spans at widths 360 – 640 mm / q (kN / m)																		
b	h	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	15,0	20,0	25,0	30,0
120	360	10,95 f	9,57 f	8,69 f	8,07 f	7,59 f	7,21 f	6,90 f	6,63 f	6,41 f	6,03 f	5,71 M	5,34 M	5,03 M	4,78 M	4,55 M	4,36 M	3,90 M	3,38 M	2,76 Q	2,30 Q
140	360	11,53 f	10,07 f	9,15 f	8,50 f	7,99 f	7,59 f	7,26 f	6,98 f	6,74 f	6,35 f	6,03 f	5,76 f	5,44 M	5,16 M	4,92 M	4,71 M	4,21 M	3,65 M	3,23 Q	2,69 Q
160	360	12,05 f	10,53 f	9,57 f	8,88 f	8,36 f	7,94 f	7,59 f	7,30 f	7,05 f	6,63 f	6,30 f	6,03 f	5,80 f	5,51 M	5,26 M	5,03 M	4,50 M	3,90 M	3,49 M	3,07 Q
180	360	12,54 f	10,95 f	9,95 f	9,24 f	8,69 f	8,26 f	7,90 f	7,59 f	7,33 f	6,90 f	6,55 f	6,27 f	6,03 f	5,82 f	5,58 M	5,34 M	4,78 M	4,14 M	3,70 M	3,38 M
200	360	12,99 f	11,34 f	10,31 f	9,57 f	9,00 f	8,55 f	8,18 f	7,87 f	7,59 f	7,15 f	6,79 f	6,49 f	6,24 f	6,03 f	5,84 f	5,63 M	5,03 M	4,36 M	3,90 M	3,56 M
240	360	13,80 f	12,05 f	10,95 f	10,17 f	9,57 f	9,09 f	8,69 f	8,36 f	8,07 f	7,59 f	7,21 f	6,90 f	6,63 f	6,41 f	6,20 f	6,03 f	5,51 M	4,78 M	4,27 M	3,90 M
120	400	12,17 f	10,63 f	9,66 f	8,97 f	8,44 f	8,02 f	7,67 f	7,37 f	7,12 f	6,70 f	6,34 M	5,93 M	5,59 M	5,31 M	5,06 M	4,84 M	4,33 M	3,75 M	3,07 Q	2,56 Q
140	400	12,81 f	11,19 f	10,17 f	9,44 f	8,88 f	8,44 f	8,07 f	7,76 f	7,49 f	7,05 f	6,70 f	6,41 f	6,04 M	5,73 M	5,47 M	5,23 M	4,68 M	4,05 M	3,58 Q	2,99 Q
160	400	13,39 f	11,70 f	10,63 f	9,87 f	9,29 f	8,82 f	8,44 f	8,11 f	7,83 f	7,37 f	7,00 f	6,70 f	6,44 f	6,13 M	5,84 M	5,59 M	5,00 M	4,33 M	3,88 M	3,41 Q
180	400	13,93 f	12,17 f	11,06 f	10,26 f	9,66 f	9,18 f	8,78 f	8,44 f	8,15 f	7,67 f	7,28 f	6,97 f	6,70 f	6,47 f	6,20 M	5,93 M	5,31 M	4,60 M	4,11 M	3,75 M
200	400	14,43 f	12,60 f	11,45 f	10,63 f	10,00 f	9,50 f	9,09 f	8,74 f	8,44 f	7,94 f	7,54 f	7,21 f	6,94 f	6,70 f	6,49 f	6,25 M	5,59 M	4,84 M	4,33 M	3,96 M
240	400	15,33 f	13,39 f	12,17 f	11,30 f	10,63 f	10,10 f	9,66 f	9,29 f	8,97 f	8,44 f	8,02 f	7,67 f	7,37 f	7,12 f	6,89 f	6,70 f	6,13 M	5,31 M	4,75 M	4,33 M
160	440	14,73 f	12,87 f	11,69 f	10,86 f	10,22 f	9,70 f	9,28 f	8,92 f	8,62 f	8,11 f	7,70 f	7,37 f	7,08 f	6,74 M	6,43 M	6,15 M	5,50 M	4,77 M	4,26 M	3,75 Q
180	440	15,32 f	13,39 f	12,16 f	11,29 f	10,62 f	10,09 f	9,65 f	9,28 f	8,96 f	8,43 f	8,01 f	7,66 f	7,37 f	7,11 f	6,82 M	6,53 M	5,84 M	5,06 M	4,52 M	4,13 M
200	440	15,87 f	13,86 f	12,60 f	11,69 f	11,00 f	10,45 f	10,00 f	9,61 f	9,28 f	8,73 f	8,30 f	7,94 f	7,63 f	7,37 f	7,14 f	6,88 M	6,15 M	5,33 M	4,77 M	4,35 M
240	440	16,87 f	14,73 f	13,39 f	12,43 f	11,69 f	11,11 f	10,62 f	10,22 f	9,86 f	9,28 f	8,82 f	8,43 f	8,11 f	7,83 f	7,58 f	7,37 f	6,74 M	5,84 M	5,22 M	4,77 M
160	480	16,07 f	14,04 f	12,76 f	11,84 f	11,14 f	10,59 f	10,13 f	9,74 f	9,40 f	8,85 f	8,40 f	8,04 f	7,73 f	7,35 M	7,01 M	6,71 M	6,00 M	5,20 M	4,65 M	4,10 Q
180	480	16,72 f	14,60 f	13,27 f	12,32 f	11,59 f	11,01 f	10,53 f	10,13 f	9,78 f	9,20 f	8,74 f	8,36 f	8,04 f	7,76 f	7,44 M	7,12 M	6,37 M	5,51 M	4,93 M	4,50 M
200	480	17,31 f	15,13 f	13,74 f	12,76 f	12,00 f	11,40 f	10,91 f	10,49 f	10,13 f	9,53 f	9,05 f	8,66 f	8,32 f	8,04 f	7,79 f	7,50 M	6,71 M	5,81 M	5,20 M	4,75 M
240	480	18,40 f	16,07 f	14,60 f	13,56 f	12,76 f	12,12 f	11,59 f	11,14 f	10,76 f	10,13 f	9,62 f	9,20 f	8,85 f	8,54 f	8,27 f	8,04 f	7,35 M	6,37 M	5,70 M	5,20 M
160	520	17,41 f	15,21 f	13,82 f	12,83 f	12,07 f	11,47 f	10,97 f	10,55 f	10,18 f	9,58 f	9,10 f	8,71 f	8,37 f	7,97 M	7,60 M	7,27 M	6,50 M	5,63 M	5,04 M	4,44 Q
180	520	18,11 f	15,82 f	14,37 f	13,34 f	12,56 f	11,93 f	11,41 f	10,97 f	10,59 f	9,97 f	9,47 f	9,05 f	8,71 f	8,41 f	8,06 M	7,71 M	6,90 M	5,97 M	5,34 M	4,88 M
200	520	18,76 f	16,39 f	14,89 f	13,82 f	13,01 f	12,35 f	11,82 f	11,36 f	10,97 f	10,32 f	9,81 f	9,38 f	9,02 f	8,71 f	8,43 f	8,13 M	7,27 M	6,30 M	5,63 M	5,14 M
240	520	19,93 f	17,41 f	15,82 f	14,69 f	13,82 f	13,13 f	12,56 f	12,07 f	11,66 f	10,97 f	10,42 f	9,97 f	9,58 f	9,25 f	8,96 f	8,71 f	7,97 M	6,90 M	6,17 M	5,63 M
160	560	18,75 f	16,38 f	14,88 f	13,82 f	13,00 f	12,35 f	11,81 f	11,36 f	10,97 f	10,32 f	9,80 f	9,38 f	9,01 f	8,58 M	8,18 M	7,83 M	7,00 M	6,07 M	5,43 M	4,78 Q
180	560	19,50 f	17,04 f	15,48 f	14,37 f	13,52 f	12,85 f	12,29 f	11,81 f	11,41 f	10,73 f	10,20 f	9,75 f	9,38 f	9,05 f	8,68 M	8,31 M	7,43 M	6,43 M	5,75 M	5,25 M
200	560	20,20 f	17,65 f	16,03 f	14,88 f	14,01 f	13,30 f	12,73 f	12,24 f	11,81 f	11,12 f	10,56 f	10,10 f	9,71 f	9,38 f	9,08 f	8,76 M	7,83 M	6,78 M	6,07 M	5,54 M
240	560	21,47 f	18,75 f	17,04 f	15,82 f	14,88 f	14,14 f	13,52 f	13,00 f	12,55 f	11,81 f	11,22 f	10,73 f	10,32 f	9,96 f	9,65 f	9,38 f	8,58 M	7,43 M	6,64 M	6,07 M
160	600	20,09 f	17,55 f	15,95 f	14,80 f	13,93 f	13,23 f	12,66 f	12,17 f	11,75 f	11,06 f	10,50 f	10,05 f	9,66 f	9,19 M	8,76 M	8,39 M	7,50 M	6,50 M	5,81 M	5,12 Q
180	600	20,90 f	18,25 f	16,59 f	15,40 f	14,49 f	13,76 f	13,16 f	12,66 f	12,22 f	11,50 f	10,92 f	10,45 f	10,05 f	9,70 f	9,30 M	8,90 M	7,96 M	6,89 M	6,17 M	5,63 M
200	600	21,64 f	18,91 f	17,18 f	15,95 f	15,01 f	14,25 f	13,63 f	13,11 f	12,66 f	11,91 f	11,31 f	10,82 f	10,40 f	10,05 f	9,73 f	9,38 M	8,39 M	7,27 M	6,50 M	5,93 M
240	600	23,00 f	20,09 f	18,25 f	16,95 f	15,95 f	15,15 f	14,49 f	13,93 f	13,45 f	12,66 f	12,02 f	11,50 f	11,06 f	10,68 f	10,34 f	10,05 f	9,19 M	7,96 M	7,12 M	6,50 M
160	640	21,43 f	18,72 f	17,01 f	15,79 f	14,86 f	14,12 f	13,50 f	12,98 f	12,53 f	11,79 f	11,20 f	10,72 f	10,30 f	9,80 M	9,35 M	8,95 M	8,00 M	6,93 M	6,20 M	5,46 Q
180	640	22,29 f	19,47 f	17,69 f	16,42 f	15,45 f	14,68 f	14,04 f	13,50 f	13,03 f	12,27 f	11,65 f	11,14 f	10,72 f	10,35 f	9,91 M	9,49 M	8,49 M	7,35 M	6,58 M	6,00 M
200	640	23,09 f	20,17 f	18,32 f	17,01 f	16,01 f	15,20 f	14,54 f	13,98 f	13,50 f	12,70 f	12,07 f	11,54 f	11,10 f	10,72 f	10,38 f	10,01	8,95 M	7,75 M	6,93 M	6,33 M
240	640	24,53 f	21,43 f	19,47 f	18,08 f	17,01 f	16,16 f	15,45 f	14,86 f	14,35 f	13,50 f	12,82 f	12,27 f	11,79 f	11,39 f	11,03 f	10,72 f	9,80 M	8,49 M	7,59 M	6,93 M