

Glued laminated timber — Performance requirements and minimum production requirements

The European Standard EN 386:2001 has the status of a
British Standard

ICS 79.040

National foreword

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 124 "Timber structures", the secretariat of which is held by DS.

This European Standard supersedes EN 386:1995.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2002, and conflicting national standards shall be withdrawn at the latest by April 2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

Glued laminated timber is obtained by bonding together a number of laminations having their grain essentially parallel. In this way a member with a rectangular solid cross-section can be produced.

The purpose of the requirements in this standard is to obtain reliable and durable bonding, so that the bonds in the glued laminated timber will maintain their integrity throughout the intended life of the structure. The requirements will need to be supplemented to take into consideration special production conditions, materials or functional requirements. The requirements apply to structural members of service classes 1 and 2. For timber structures of service class 3 special precautions shall be taken, for example weather resistant adhesives shall be used. The requirements for these are given in EN 301.

1 Scope

This standard specifies requirements for the components of glued laminated timber members and minimum requirements for the production of such members for structural use.

This standard is applicable to products with a finished lamination thickness of not more than 45 mm.

Although most glued laminated timber is made from coniferous species this standard also applies to broad leaved species if information is available to enable them to be satisfactorily bonded.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 301, *Adhesives, phenolic and aminoplastic for load-bearing timber structures - Classification and performance requirements.*

EN 385:2001, *Finger jointed structural timber - Performance requirements and minimum production requirements.*

EN 391:2001, *Glued laminated timber - Delamination test of glue lines.*

EN 392, *Glued laminated timber - Shear test of glue lines.*

prEN 14081-1:2000, *Timber structures - Strength graded structural timber with rectangular cross section - Part 1: General requirements.*

prEN 14081-2:2000, *Timber structures - Strength graded structural timber with rectangular cross section - Part 2: Machine Grading - Additional requirements for initial type testing.*

prEN 14081-3:2000, *Timber structures - Strength graded structural timber with rectangular cross section - Part 3: Machine Grading - Additional requirements for factory production control.*

3 Terms and definitions

For the purposes of this European Standard the following terms and definitions given in EN 391 and the following apply:

3.1

adhesive type

adhesive types I and II, see EN 301

3.2

glued laminated timber (glulam)

structural member formed by bonding together timber laminations with their grain running essentially parallel

3.3

horizontal glulam

glued laminated timber with the glue line planes perpendicular to the long length of the cross section, see Figure 1a

3.4

vertical glulam

glued laminated timber with the glue line planes perpendicular to the short length of the cross section, see Figure 1b

3.5

service class 1

service class characterized by a moisture content in the materials corresponding to a temperature of 20 °C and the relative humidity of the surrounding air only exceeding 65 % for a few weeks per year

NOTE In service class 1 the average equilibrium moisture content in most softwoods will not exceed 12 %.

3.6

service class 2

service class characterized by a moisture content in the materials corresponding to a temperature of 20 °C and the relative humidity of the surrounding air only exceeding 85 % for a few weeks per year

NOTE In service class 2 the average equilibrium moisture content in most softwoods will not exceed 20 %.

3.7

service class 3

service class characterized by climatic conditions leading to higher moisture contents than service class 2

3.8

maximum delamination percentage

see EN 391

3.9

total delamination percentage

see EN 391

3.10

wood failure percentage

see EN 392

5.3 Adhesives

The adhesive shall enable joints of such strength and durability to be produced in order that the integrity of the bond is maintained throughout the intended lifetime of the structure.

Acceptable strength and durability can be achieved by the use of an adhesive of type I and shall meet the requirements for this type given in EN 301. Or, for structures in service class 1 or 2 an adhesive of type II according to EN 301 can be used, provided the temperature of the member in the structure will always be below 50 °C.

NOTE 1 For the lamination and the end jointing, the adhesive should be chosen considering the climatic conditions in service, the timber species, the preservative used (if any) and the production methods.

NOTE 2 Such strength and durability can be achieved by a polycondensation adhesive of the phenolic or aminoplastic type as defined in EN 301.

For adhesives of other types than covered by EN 301 a bond with equivalent durability and strength shall be achieved. Special considerations shall be given to creep failure, the ability to maintain structural integrity during fire and elevated temperature and moisture conditions in ordinary service.

5.4 End joints in laminations

The characteristic bending strength $f_{m,k}$ obtained from flatwise bending tests of the end joints shall meet the following requirement:

$$f_{m,k} \geq f_{m,dc,k}$$

where

$f_{m,dc,k}$ is the declared characteristic bending strength.

The flatwise bending tests shall be performed in conformity with EN 385.

The characteristic bending strength shall be determined from the Log-Normal probability distribution function.

5.5 Glue line integrity and strength

5.5.1 The requirements for glue line integrity shall be based on testing of the glue line in a full cross-sectional specimen, cut from the manufactured glulam member. The specimens shall be representative of the manufacture.

5.5.2 For structures of service class 3, delamination tests shall be made in conformity with method A of EN 391.

For structures of service class 1 or 2 the testing shall be either delamination tests in conformity with method A of EN 391 or block shear tests in conformity with EN 392.

NOTE For routine quality control the test methods specified may be substituted by the following: Delamination method A may be substituted by delamination method B of EN 391:2001. For members to be used in service class 1 or 2 block shear tests may be substituted by delamination method C of EN 391:2001.

5.5.3 Depending on the method and number of cycles the total delamination percentage of each cross-sectional specimen shall be less than the values given in Table 1.

Table 1 - Maximum values for the total delamination percentages

Method	Applicable to adhesive type	Max. total delamination percentage after cycle no.:		
		1	2	3
A	Type I	-	5	10
B	Type I	4	8	-
C	Type II	10	-	-

For all delamination methods the maximum delamination percentage shall be less than or equal to 40 %.

5.5.4 Each test result from the block shear tests of each cross-sectional specimen shall comply with the following requirements with regard to the shear strength and the wood failure percentage.

The shear strength of each glue line shall be at least 6,0 N/mm². For Coniferous wood and Poplar a shear strength of 4,0 N/mm² shall be regarded as acceptable if the wood failure percentage is 100, see Table 2, individual values.

The average wood failure percentage over a cross-sectional specimen and any individual value shall exceed the minimum wood failure percentages stated in Table 2.

Table 2 - Minimum wood failure percentages, WFP, relating to the shear strength f_v . For values in between, linear interpolation shall be used

Shear strength f_v in N/mm ²	Average			Individual values		
	6	8	$f_v \geq 11$	$4 \leq f_v < 6$	6	$f_v \geq 10$
Minimum wood failure percentage, % ¹⁾	90	72	45	100	74	20

¹⁾ For average values the minimum wood failure percentage is: $144 - (9 f_v)$. For the individual values the minimum wood failure percentage for the shear strength $f_v \geq 6,0$ N/mm² is: $153,3 - (13,3 f_v)$.

6 Manufacturing requirements

6.1 Production conditions

6.1.1 General

The staff shall have the necessary skill for the production of glulam and the grading of the timber.

6.1.2 Premises

6.1.2.1 The premises shall be suitable for all phases of the production, taking into consideration the requirements given in this standard.

Special consideration shall be given to

- a) size of the members to be produced;
- b) air temperature;
- c) relative humidity of the air.

6.1.2.2 The temperature in the production area shall be at least 15 °C. During curing of the members a higher temperature is required, see 6.4.4, but this requirement may be limited to a specific part of the premises (curing chambers).

6.1.2.3 During the production the relative humidity of the air shall be in the range of 40 % to 75 %. During curing 30 % is acceptable. Deviations from this range are acceptable for short periods during the day.

6.1.2.4 Drying and storage facilities of sufficient capacity shall be available to enable the required moisture content and temperature of the timber to be achieved.

6.1.2.5 Where pre-dried timber is used, storage facilities shall be available to maintain the required moisture content of the timber.

6.1.2.6 Unless resin and hardener are pumped directly from storage tanks and mixed automatically during application, there shall be a separate room for the preparation of the adhesive (mixing of resin and hardener). There shall also be suitable resin and hardener storage facilities and an area for cleaning the adhesive equipment.

The resin and hardener storage shall be arranged so that the 'first in first out' principle is maintained.

6.1.3 Equipment

Equipment shall be available:

- a) to monitor continuously the temperature and relative humidity of the air (thermo hygrograph) in storage, production and curing areas;
- b) to measure the moisture content of the timber and for checking (calibrating) moisture meters;
- c) for machine and visual grading when these operations are carried out by the producer;
- d) to make end joints in the laminations with sufficient and reliable strength;
- e) to measure lamination thickness;
- f) to provide surfaces fulfilling the requirements of the thickness tolerances and surface quality (usually a lamination planer, see 6.4.1.5 and 6.4.1.6);
- g) for weighing and mixing resin and hardener in the required proportions;
- h) for the uniform application of the required quantity of adhesive;
- i) to obtain the required glue line pressure, temperature and relative humidity of the air during curing of the adhesive;
- j) to test the strength of end joints in the laminations;
- k) to test the integrity of the glue lines.

6.2 Timber

6.2.1 Species

Only species or a mixture of species proven to be suitable for glulam production shall be used.

NOTE In most European countries the following suitable timber species are available: European whitewood (*Picea abies*, *Abies alba*); European redwood (*Pinus sylvestris*); Douglas Fir (*Pseudotsuga menziesii*).

In addition the following species: (Western) Hemlock (*Tsuga heterophylla*), Corsican Pine and Austrian black pine (*Pinus nigra*); Larch (*Larix decidua*); Maritime Pine (*Pinus pinaster*); Poplar (*Populus robusta*, *Populus alba*); Radiata Pine (*Pinus radiata*); Sitka spruce (*Picea sitchensis*); Western red cedar (*Thuja plicata*), have been used for glued laminated timber production.

6.2.2 Moisture content

The required moisture content of the laminations depends on whether or not the timber used has been preservative treated.

Non-treated timber. At assembly, the moisture content in every lamination shall be in the range of 8 % to 15 %. The range of moisture content of the laminations in a glulam member shall be not greater than 4 %.

Treated timber. At assembly the moisture content in every lamination shall be in the range of 11 % to 18 %. The range of moisture content of the laminations in a glulam member shall be not greater than 4 %.

6.2.3 Thickness and cross-sectional area

The finished thickness and cross-sectional area of any lamination shall not exceed the values given in Table 3.

Table 3 - Maximum finished thickness t and maximum cross-sectional area A of the laminations to be used in structures in the service classes mentioned

	Service class 1		Service class 2		Service class 3	
	t mm	A mm ²	t mm	A mm ²	t mm	A mm ²
Species type:						
Conifers	45	12 000	45	12 000	35	10 000
Broad leaf	40	7 500	40	7 500	35	6 000

For curved members the maximum thickness is also governed by the radius r of curvature of the laminates and the characteristic bending strength of the end joints. The finished thickness t shall comply with

$$t \leq \frac{r}{250} \left(1 + \frac{f_{m,dc,k}}{80} \right)$$

6.3 Adhesives

The adhesive shall comply with 5.3.

6.4 Manufacture

6.4.1 Laminations

6.4.1.1 The individual laminations shall be end jointed to the final length before planing. During this operation the temperature of the timber shall not be less than 15 °C.

6.4.1.2 In order to reduce cupping and cracking, laminations with a width larger than 200 mm shall be grooved. In each lamination one groove is permitted in the middle part of the cross section, with a maximum width of 4 mm and a maximum depth of one third of the lamination thickness.

Grooves in adjacent laminations shall be staggered by at least the thickness of the laminations.

6.4.1.3 When laminations are jointed by finger joints these shall be produced in conformity with EN 385. Meanwhile, the full end pressure needs only to be applied for at least 1 s.

The moisture content of the individual boards shall comply with 6.2.2 of this standard.

NOTE The more relaxed requirements in 6.2 in EN 385:2001 are not valid for finger joints in glulam members.

6.4.1.4 Where a lamination for horizontal glulam consists of two boards side by side and the edges are not bonded, the edge-joints in adjacent laminations shall be staggered laterally by at least the lamination thickness. For members used in service class 1 or 2 the outer lamination on each face shall be edge-bonded. For members to be used in service class 3 the outer four laminations on each face shall be edge-bonded.

Laminations in vertical glulam are not required to be edge-bonded, but the edge-joints in adjacent laminations shall be staggered by at least one third of the board width. In members to be used in service class 3 the outer laminations shall be edge-bonded.

6.4.1.5 The laminations shall be planed or similarly finished before bonding. The planing shall be carried out not more than 24 h before bonding, unless the species and the storage environment are such that unacceptable surface changes will not take place. With species that are difficult to bond, e.g. have a high resin content or where the laminations have been treated with preservative, planing shall be carried out within 6 h of bonding.

6.4.1.6 For gap filling adhesives capable of a glue line thickness of 1 mm the maximum permitted deviation from the average thickness within a lamination length of 1 m is 0,2 mm. Where non-gap filling adhesives are used the limit deviation shall not exceed 0,1 mm.

The difference in thickness over the cross-sectional width of the lamination shall be less than 0,15 % of the width and in no case shall it exceed 0,3 mm.

Some adhesives may require smaller thickness tolerances.

6.4.2 Bonding

6.4.2.1 At the time of bonding the surfaces of laminations shall be clean.

6.4.2.2 The adhesive spread shall be uniform and in sufficient quantity in accordance with the recommendations of the adhesive manufacturer.

NOTE Usually a minimum spread of 350 g/m² is required, except for high frequency curing, where the minimum is 200 g/m².

6.4.2.3 The laminations shall generally have the pith to the same side, see Figure 2a). For glulam to be used in service class 3 the extreme laminations on either edge shall have the pith side facing outwards, see Figure 2b).



a) General orientation b) Orientation in glulam for service class 3

Figure 2 - Orientation of laminations in the cross section

6.4.3 Cramping

6.4.3.1 The cramping arrangement shall ensure a uniform pressure over the glue line.

6.4.3.2 The pressure shall be that specified in the adhesive manufacturer's instructions for the adhesive used. Recommended values are given in Table 4. For curved members higher cramping pressures shall be applied and in such a way that the laminations can slide over each other in the lengthwise direction to avoid open glue lines.

Table 4 - Recommended cramping pressures for conifers

Lamination thickness <i>t</i> , in mm	$t \leq 35$	$35 < t \leq 45$
Pressure, in N/mm ²	0,6	0,8 with grooves 1,0 without grooves

6.4.3.3 Sufficient pressure shall be maintained during cramping. Tightening-up shall be carried out as necessary, and in all cases immediately after initial cramping.

6.4.4 Curing and conditioning

6.4.4.1 The adhesive manufacturers instructions shall be followed. The larger part of the curing shall take place in an area with a temperature of at least 20 °C for an initial wood temperature above 18 °C and 25 °C for an initial wood temperature above 15 °C.

The temperature during curing shall be less than the maximum temperature prescribed by the adhesive manufacturer.

6.4.4.2 The time from initial cramping until the start of the temperature raising to the curing level shall not exceed 8 h.

6.4.4.3 During curing the relative humidity of the air shall be not less than 30 %. See also 6.1.2.3.

6.4.4.4 Glulam members shall not be loaded or exposed to temperatures below 15 °C until the adhesive has cured completely.

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NOTE It is recommended that this requirement is kept for at least 72 h after the end of cramping for phenolic based adhesives and 24 h for aminoplastic based adhesives.

7 Quality Control

7.1 Factory production control

7.1.1 General

7.1.1.1. To ensure that the produced glulam members conform with this standard, the manufacturer shall establish and maintain documented internal factory production control.

The documented factory production control shall be efficiently implemented by means of procedures and instructions.

7.1.2 End joints

7.1.2.1 From each work shift and each production line a representative sample of end joints shall be drawn and tested in flatwise bending as described in EN 385. Only full size end joints shall be tested.

7.1.2.2 For each production line and declared strength value and shift the bending strength is acceptable if one of the following conditions a) or b) is met:

- a) Of the last 100 joints tested, the values of the flatwise bending strength f_m of each single joint shall relate to the threshold value $f_{m,dc,k}$:

Not more than 5 shall be below the threshold value and

No value shall fall below 90 % of the threshold value.

- b) The characteristic bending strength $f_{m,15,k}$ of the last 15 finger joints is larger than or equal to the characteristic flatwise bending strength of the finger joints $f_{m,dc,k}$ declared by the manufacturer:

$$f_{m,15,k} \geq f_{m,dc,k}$$

The characteristic bending strength of the finger joints, declared by the manufacturer, shall be stated.

The characteristic bending strength $f_{m,15,k}$ shall be determined as described in 7.1.4 of EN 385:2001.

7.1.3 Gluing record

7.1.3.1 A gluing record shall be kept containing:

- a) date and number of production;
- b) species;
- c) timber grade or strength class;
- d) dimensions of the member;
- e) moisture content of the timber;
- f) time for start of adhesive application;
- g) time for start and end of the cramping process;
- h) cramping pressure;

- i) adhesive, e.g. resin and hardener;
- j) adhesive spread (g/m^2);
- k) calibration of moisture meter.

The gluing record shall be signed by the nominated responsible member of staff.

7.1.3.2 The details of temperature and relative humidity of the air in timber storage, end jointing room, gluing and cramping area shall be recorded.

7.1.4 Glue line integrity

7.1.4.1 The glue lines shall be tested in a full cross-sectional specimen, which is to be cut from a cured glulam member produced during each working shift. For each shift in which gluing is carried out one full cross-sectional specimen shall be taken for each 20 m^3 of production or part thereof.

If all tests for a three-months period satisfy the requirements the number of samples may be reduced to not less than half the number prescribed above.

7.1.4.2 The results of the testing for glue line integrity shall be documented as described in EN 391 and EN 392 for delamination and block shear respectively.

7.2 Organization of factory production control

7.2.1 Responsibility and authority

The responsibility, authority and the interrelation of all personnel who manage, perform and verify work affecting quality shall be defined, particularly for personnel who need the organizational freedom and authority to

- a) initiate action to prevent the occurrence of non-conformity of glulam members;
- b) identify and record any quality problems with glulam members.

7.2.2 Delegated by the manufacturer

At every factory unit the manufacturer shall appoint a person who shall have appropriate authority, knowledge and experience of the production of glulam to be responsible for conducting and supervising factory production control procedures and ensuring that the requirements given in this standard are implemented and maintained.

7.2.3 Inspection by the manufacturer

The production control system adopted to satisfy the requirements of this standard shall be reviewed at appropriate intervals by the manufacturer's management to ensure its continuing suitability and effectiveness. Records of such reviews shall be maintained.

7.3 Documentation of the quality control system

7.3.1 The manufacturer's documentation, procedures and instructions shall be relevant to the production and process control of the glulam, and shall be adequately described in a works' quality manual, covering:

- a) quality aims and organizational structure, responsibilities and powers of the management with regard to conformity of the glulam;
- b) procedures for specifying and verifying the quality of the timber and the adhesive;

- c) manufacturing, production control and other techniques, processes and systematic actions to be used;
- d) inspections and tests that will be carried out before, during and after manufacture, and the frequency with which they are to be carried out.

NOTE The documentation of the end joint tests, the gluing record and the glue line tests may be recorded and kept separately.

7.3.2 All documentation shall be kept for at least 10 years.

7.3.3 All documentation shall be registered so that the raw materials and production conditions for each glulam member are traceable, at least to the production week and year.

7.4 Inspection and testing

7.4.1 General

All necessary facilities, equipment and personnel shall be available to carry out the necessary inspections and tests. This requirement may also be fulfilled, if by means of a contract the manufacturer or his agent involves a subcontractor having the necessary facilities, equipment and personnel. The manufacturer shall control, calibrate and maintain inspection, measuring and test equipment, whether owned by the manufacturer, or on hire, to demonstrate the conformity of the glulam members to the specified requirements of this standard. Equipment shall be used in a manner which ensures that measurement tolerances are known and are consistent with the required measurement capability.

7.4.2 Action in case of non-conformity

If there is reason to doubt the quality of any production operation or of the raw materials used, the internal quality control shall be increased and intensified.

7.4.3 Quality surveillance

If the result of the test or inspection of a glulam member is unsatisfactory, the manufacturer shall at once take the necessary steps to rectify the shortcoming. Glulam members, which do not comply with the requirements, shall be set aside and marked accordingly. When the shortcoming has been rectified, the test or inspection in question shall be repeated without delay, provided that this is technically possible and is necessary as evidence that the defects have been overcome.

If glulam members have been dispatched before the test results are available notification shall be made to customers, if necessary, for the purpose of avoiding any consequential damage.

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