

## Section 1

### Requirements for Materials, Bonding Methods and Wood Protection

#### A. General

##### 1. Classification according to the field of application

**1.1** Only proven boatbuilding wood shall be used for all timber components exposed to water and weather, i. e. timber with good resistance to water and weather, fungal attack and insect infestation, as well as with good mechanical properties that are also suitable for the particular application. Furthermore, it shall have a low swelling and shrinkage properties.

**1.2** For components not exposed to water or weather, and not requiring strength, timber of lower durability may be used.

##### 2. Quality

The timber used in boatbuilding shall be long-grained and of the best quality, i. e. be free from sap, shakes, objectionable knots and other defects. Twisted-grown or rough saw cut wood shall not be used.

##### 3. Drying

**3.1** The timber used shall be well seasoned and sufficiently dried, or shall be correctly dried in a suitable drying kiln.

**3.2** For this purpose, the timber shall be stacked in piles which are as small as possible, so that uniform drying is guaranteed.

**3.3** In the case of forced drying, the residual moisture content shall not be more than 10 %. When processing, this content shall not exceed a maximum of 15 % as a result of hygroscopic behaviour.

**3.4** The moisture content shall be determined by establishing the loss of mass of a sample between its state at the time of draw-off and its state after drying, based on constant weight at  $103 \pm 2$  °C and the calculation of the weight loss as a percentage of the dry mass. This shall be done in accordance with DIN 52375 or ISO 9425.

#### B. Types of Wood and Classifications

##### 1. Solid wood

**1.1** Radially sawn timber shall mainly be used for boatbuilding. The angle of the annual rings to the lower sawn edge shall not be less than 45°.

**1.2** Table 2.1.2 shows the number of different types of timber and their most important properties, such as durability, specific gravity, as well as bending, tensile and compressive strength. Since these properties can vary in the case of timber of the same type, or even within the same trunk, no absolute values are indicated in the table, but rather reference values. The timber listed is divided into durability groups from I to V, whereby:

I = very good

II = good

III = average

IV = moderate

V = poor

**1.3** The timber used in boatbuilding shall, if exposed to the weather or used for the primary structural components of a boat, belong to at least durability group III.

**1.4** In place of the timber listed in Table 2.1.2, other types can be used if the durability and the technological values are verified and are equivalent. The manufacturer shall always be responsible for the correct selection of the quality and type of wood.

**1.5** Since wood has anisotropic material properties, these shall be taken into account during the design of the components. It shall be ensured that the main direction of stress lies in the direction of the greatest strength of wood, and that no impairment of function of the component is caused through the directional moisture coefficient of expansion.

**1.6** The safety factors used in the strength calculations shall be agreed on in each case with GL.

## 2. Plywood

### 2.1 General

**2.1.1** Plywood consists of individual layers which are bonded together. In general, the layers can comprise veneers, wooden slats or small wooden slats. The panels described in this Regulation as plywood shall consist exclusively of veneer layers.

**2.1.2** The plywood panels consist of at least three veneers bonded transversely to each other (Table 2.1.1 or 2.1.3) by means of curable synthetic resin adhesives. The resistance of the adhesives to water and weather shall be demonstrated by long-term and outdoor testing. The number of veneer layers is dependent on the thickness and is defined in sub-sections C. "Boatbuilding Plywood" and D. "Plywood for aircrafts".

### 2.2 Grades

**2.2.1** The plywood panels are divided into two grades GL I and GL II.

**2.2.2** Both grades are identical with regard to required strengths, including resistance to adhesives. The only distinction is that the panels of grade GL I are suitable for use in one piece, whilst those of grade GL II may, because of non-permissible defects in the middle and outer layers, only be used separately after removal of the defects.

### 2.3 Panel dimensions

**2.3.1** The dimensions of the plywood panels are to be specified by the customer, if standard dimensions in accordance with DIN 4078 are not used.

**2.3.2** The length of the panels is measured parallel to the grain of the outer layer, and is always specified first. The longitudinal and lateral tolerances are  $\pm 5$  mm.

**2.3.3** The permissible thickness deviation is:

up to 3 mm  $\pm 10$  %

over 3 mm  $\pm 5$  %, but maximum  $\pm 0,5$  mm

### 2.4 Bonding

**2.4.1** The plywood panels shall be bonded without flaws (BFU 100 in accordance with DIN 68705). For this purpose, compliance with all decisive factors such as wood moisture content, pressing power, pressing temperature, pressing duration, glue characteristics, charging etc. shall be observed continually and carefully.

At present, the following synthetically-based adhesives are approved by GL for plywood production:

- Phenolic adhesive (including phenolic adhesive film)
- Melamine resin adhesives
- Resorcinol resin adhesives

**2.4.2** If a new glue is used, then faultless, error-free handling and bonding shall be demonstrated to GL as well as absolute resistance to water and boiling.

### 2.5 Structure and requirements

Different regulations apply to the structures and plywood panels used in boatbuilding and aviation, as listed in sub-sections C. and D. respectively.

### 2.6 Certificates

**2.6.1** Germanischer Lloyd issues certificates for tested and approved plywood panels, and these are handed over to the manufacturer and/or customer.

**2.6.2** The certificate specifies, among other things, the plywood type, the number of plywood panels inspected, the stamping and, if requested, the average values of the test results.

**2.6.3** Independent of the testing by Germanischer Lloyd, the manufacturer is obliged to continually carry out his own shop-based quality control during all working steps, the selection of the wood and its processing during production of the plywood panels.

### 2.7 Storage of the plywood panels

**2.7.1** Finished plywood panels which are placed in storage shall be kept in closed rooms and stored horizontally.

**2.7.2** The plywood panels shall only be placed in horizontal stores that are at least 30 cm above the ground and from the walls, in order to avoid the effects of moisture.

**2.7.3** The individual piles shall be protected against moisture from one side by covering panels.

**2.7.4** Non-compliance with these storage regulations can lead to previous tests being declared invalid.

### 2.8 Strength calculations

The safety factors used in the strength calculations shall be agreed on, in each case, with GL.

## C. Boatbuilding Plywood

### 1. General

**1.1** All plywood components exposed to water and weather, or used in primary structural components (such as the deck, shell and bulkheads), shall be produced from boatbuilding plywood that has been tested and in compliance with Section 10.6.

**1.2** Boatbuilding plywood consists of at least three veneers bonded crosswise together (Table 2.1.1) by means of curable synthetic-resin adhesives. The resistance of these adhesives to water and weather shall be demonstrated by long-term and outdoor testing.

**1.3** As plywood can also be destroyed in suitable conditions by animal or plant pests, timber shall be used which offers a natural resistance.

**1.4** Independent of the testing by Germanischer Lloyd, the manufacturer is obliged to continually carry out his own shop-based quality control of all working steps, the selection of the wood and its processing during production of the plywood panels.

**1.5** The points listed under B.2 shall be taken into account.

**2. Structure**

**2.1** The selection of timber and the structure of the panels (number of veneer layers) shall be appropriate for the field of application. Depending on the application, strong, durable timber - e.g. makoré and the hard, durable mahogany types of strength group F1 (Table 2.1.2) - with several thin inner layers of veneer shall be selected for load-carrying components subject to high stresses. On the other hand, plywood panels of lighter, less strong, and less durable timber of strength group F2 - e.g. khaya mahogany, okumé - with thicker and fewer inner layers of veneer and good surface protection are suitable for linings.

**2.2** In general, veneers of 1,5 mm thickness are used for the outer layers. However, efforts should be made to use thicker outer layers because of the later reworking necessary in boatbuilding. However, their thickness shall not exceed 2,6 mm because of increased danger of shakes in the veneers. In the case of inner layers, veneer layers in plywood panels up to 15 mm thick may not have a thickness in excess of 2,6 mm because of potential defects. For plywood panels thicker than 15 mm, veneer layers thicker than 3.8 mm may not be used.

**2.3** Only in special cases and with the explicit permission by Germanischer Lloyd this restriction can be waived. Such plywood panels are then assigned to the strength group F2 and marked accordingly in the GL stamp.

**2.4** The following table gives a list of the required minimum number and thickness of the veneer layers:

**Table 2.1.1: Minimum number and thickness of the veneer layers**

Plywood thickness [mm]	Minimum number of veneer layers	Minimum thickness of the outer layers	Greatest thickness of the inner layers
Up to 6	3		
Over 6 to 10	5	1,5 mm	2,6 mm
Over 10 to 15	7		
Over 15 to 20	7		
Over 20 to 26	9		
Over 26 to 34	11	1,5 mm	3,8 mm
Over 34 to 40	13		
Over 40 to 48	15		
Over 48 to 55	17		

**2.5** The veneer layers shall be symmetrical around the middle layer, both with respect to the grain as well as to the thickness of the layers.

**2.6** The strength of the plywood panel can be increased, or its property adapted to specific requirements, through an increased number of veneer layers, addition of extra glue and increased pressing power, as well as through insertion of fabric layers.

**2.7** For the production of boatbuilding plywood panels, only wood which is of the best quality, flawless, healthy, free from sap and spring wood shall be used for the outer and inner layers.

**3. Veneer joints**

**3.1** The joints shall be sealed perfectly and shall bond the veneers to each other by butt joints. The joints shall be glued on a suitable joint bonding machine.

**3.2** The strips of veneer of the outer layers shall be put together so that they match with regard to timber and colour.

**3.3** Sealed joints between all layers are a precondition for boatbuilding plywood panels.

**3.4** Paper or plastic adhesive strips may not be used to secure or repair inner veneer layers.

**3.5** The joints of the different veneer layers shall be staggered.

**3.6** Metal clamps used for securing purposes may only be positioned on the edges of the panels. They shall on no account remain on the panels when they are cut to standard dimensions.

#### 4. Strength groups

**4.1** With regard to their suitability for the production of boatbuilding plywood, the types of timber listed in Table 2.1.2 are currently approved. The timber is subdivided into two strength groups. Also shown is the natural durability and weathering resistance of the mentioned types of timber.

**4.2** The plywood panels may be manufactured from one or several of the approved kinds of timber. If panels comprise different types of timber of both strength groups, then all panels are assigned to the group with the lower strength and are provided with the roller stamp of the strength group F2.

**4.3** All boatbuilding plywood panels which are manufactured according to special specifications and conditions of the customer, or deviate from GL requirements, are assigned to the appropriate group and stamped according to the plywood type.

**4.4** Other types of wood may only be used for making plywood panels upon agreement with GL. The manufacturer shall always remain responsible for the correct selection of the quality and type of wood.

#### 5. Plywood grades

**5.1** Boatbuilding plywood of the two strength groups is subdivided into two grades after inspecting its external and internal quality. In relation to their respective groups, grades I and II are identical with regard to type of wood, strength, production and bonding. They differ insofar that the panels of grade I can be used completely, while the panels of grade II are restricted to partial use because of local manufacturing defects or timber flaws.

**5.2** The defects of grade II shall be limited to one third of the area of the panel. Two thirds of the panel shall be free of defects and suitable for use. The defects are identified during inspection by marking.

**5.3** The visible side of the plywood panel shall be manufactured virtually without any defects and, furthermore, the quality, colour and grain shall be combined in such a manner that they match. The hidden surface may have small colour differences or slight blemishes which do not influence the strength of the panel.

**Table 2.1.2 Plywood strength groups**

Timber type	Botanical name	Density, air-dried approx. [g/cm <sup>3</sup> ]	Durability	Mean tensile strength of plywood	
				Longitud. [N/mm <sup>2</sup> ]	Transverse [N/mm <sup>2</sup> ]
Strength group: F1 (for loadbearing components)					
Teak	Tectona grandis	0.64	I	≥ 40	≥ 30
Makoré	Dumoria hekelii	0.62	I	≥ 40	≥ 30
Douka	Dumoria africana	0.62	I	≥ 40	≥ 30
Utile	Entandrophragma utile	0.57	II	≥ 40	≥ 30
Sapele mahogany	Entandrophragma cylindricum	0.59	III	≥ 40	≥ 30
Oak	Quercus sp.	0.63	II	≥ 40	≥ 30
Strength group: F2 <sup>1</sup>					
Bigleaf mahogany	Switenia macrophylla	0.49	II	< 40	< 30
Khaya mahogany	Khaya ivorensis	0.45	II – III	< 40	< 30
Okumé (Gaboon)	Aucoumea klaineana	0.41	IV – V	< 40	< 30 <sup>1</sup>
<sup>1</sup> Only for non-loadbearing components					

## 6. Defects

**6.1** The following wood and production defects are not permissible in the outer and inner veneer layers:

- a) Any bonding defects
- b) Loose contra-shaving wood; strongly curly-grained, short-fibred wood growth at right angles to the run of the grain; cross-cut timber
- c) Larger, more prominent wood discolouration or mould stains which tend to cause rot and all other defects which could have a noticeable effect on the strength of the panel
- d) Wood discolouration on both sides, or strong glue bleeding on both sides
- e) Loose black (dead) knots, holes, loose joints or blocking cracks in the veneer layers
- f) Overlapping of the veneer layers (folding).

The following can be permitted:

- g) Up to three healthy tight knots of 15 mm Ø maximum for each side of the panel
- h) Up to three knots of 25 mm Ø maximum on each side of the panel which have been perfectly repaired
- i) Up to three cracks of the veneer edge which have been perfectly repaired. The cracks may be up to 1/10 of the panel length and on each side of the panel.
- j) Small local edge flaws up to 3 cm length do not have to be considered.

Only one type of permissible defects listed in g) to i) shall be present.

## 7. Repairs

**7.1** Repairs may be carried out on the finished, pressed boatbuilding plywood panels to a limited extent, provided that the quality of the panel is not impaired in any way. The repairs shall be carried out at the appropriate temperature under pressing power with a glue which is resistant to water and weather.

**7.2** Shakes of up to 1/10 of the panel length and 1 mm width, and small knot holes up to 5 mm Ø, may be repaired with wood putty of the same colour.

**7.3** Wider shakes and defects of up to 1/10 of the panel length shall be bonded so that they are weather-resistant. In doing so, care shall be taken when fitting and selecting the strips such that they are from appropriate timber and have the same colour. The repair work shall be carried out under pressure in accordance with DIN 68705 BFU 100.

## 8. Surface treatment

**8.1** After pressing, the plywood panels shall be subjected to sufficient soaking to ensure that their moisture content again rises to 6 – 12 %. The plywood panels may either remain unsanded or be lightly sanded.

**8.2** The outer layers of the plywood panels cut to their final dimensions shall be at least 1,0 mm (after the pressing and sanding) at the thinnest point. When sanding the panels, special care shall be taken to ensure that this requirement is met.

## 9. Panel dimensions

**9.1** The dimensions of the plywood panels are specified by the customer if standard dimensions are not used (see B.2.5).

## 10. Testing

### 10.1 General

**10.1.1** In general, the finished boatbuilding plywood panels are tested and approved at the manufacturing shop by surveyor of Germanischer Lloyd.

**10.1.2** The inspection of finished plywood panels outside of the manufacturing shop is carried out by GL only by way of exception and under stricter test conditions.

**10.1.3** GL reserves the right to also monitor the production of the plywood panels in the manufacturing shop.

### 10.2 Inspection of the plywood panels

**10.2.1** The condition of all boatbuilding plywood panels is inspected and tested by GL surveyors after their completion. In particular, attention is paid to bonding. The panels are allocated to the appropriate plywood strength group and grade, depending on the type of plywood and the quality and stamped.

**10.2.2** The plywood panels submitted to GL for inspection shall be examined, pre-graded, finished and then divided into test batches or orders by the manufacturer prior to inspection by the GL surveyor. Panels with faulty gluing are examined more closely to determine whether the faults are locally or present over the whole panel. If the latter is true, the entire test batch is tested with special care. If there are several such panels in a test batch, then the entire batch is rejected. If leaky joints or blocking cracks are found at the plywood edges of the inner layers, then these defects shall not be plugged before the GL inspection. The GL surveyor will decide whether these defects can be corrected, or whether the panel shall be rejected or assigned to grade II.

### 10.3 Grading of the plywood panels

**10.3.1** Grading of the panels shall be in accordance with the differences between grades I and II stipulated in sub-section C.6. The panels are marked with the appropriate grade stamp.

### 10.4 Sampling

**10.4.1** For the inspection of boatbuilding plywood panels, sample panels are taken from test batch intended for inspection and provided with a sample number.

**10.4.2** Test pieces of approx. 25 cm length and 100 cm width are removed from these sample panels and provided with the sample number of the test panel.

**10.4.3** The required samples are prepared from these sample pieces, and again provided with the sample numbers of the test panel.

**10.4.4** If only a few panels of a particular plywood type, or very thick and large panels, are submitted for inspection, and if the effort involved in cutting these panels appears to be too great, then samples can also be taken from pieces cut off the edge of these panels. For this purpose, it is necessary, when trimming these panels, to put the edge cuttings aside.

**10.4.5** The number of test panels is determined according to the following factors:

**10.4.5.1** If continuous inspections by GL in the manufacturing shop show that the production of the boatbuilding plywood panels appears to be reliable, and if the production is monitored continuously by suitable, automatic facilities or supervision, then it is not necessary to take test panels from each test batch.

**10.4.5.2** It is sufficient to select approximately 2 % (by number) of the panels from the current production to be used as samples.

**10.4.5.3** It shall be ensured that the test panels cover all plywood thicknesses and types.

**10.4.5.4** If production problems occur, or if the GL surveyor has the impression that the production is not always reliable, then the surveyor can insist on the selection a greater number of test panels.

**10.4.5.5** If one or several test panels should exhibit inadequate values during the inspection, then an additional two panels from the same test batch shall be tested. If, once again, the minimum requirements are not satisfied during this inspection, then the complete test batch shall be rejected.

### 10.5 Sample type and quantity

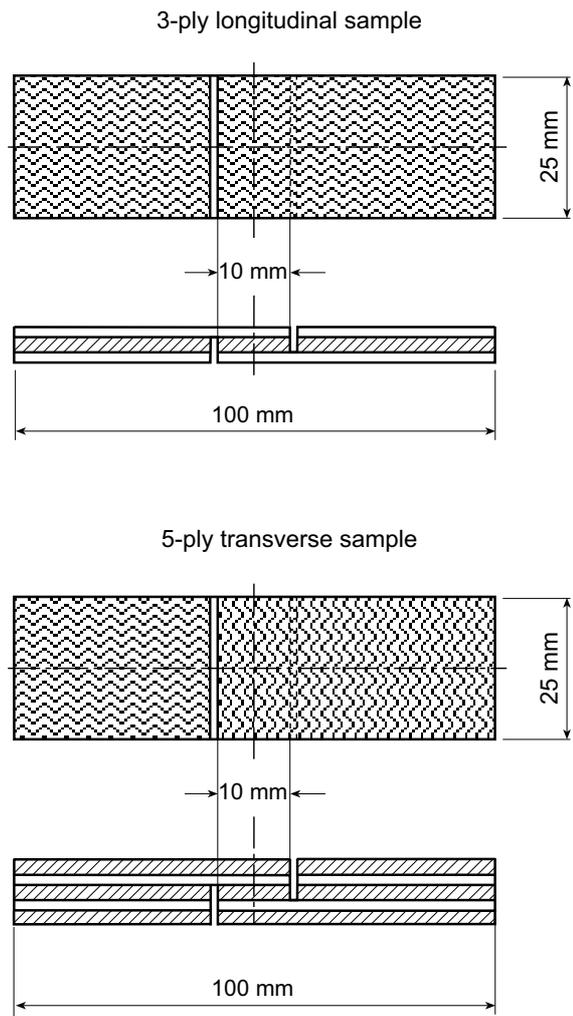
From every test panel (or test strip) to be tested, the following samples shall taken and prepared:

**10.5.1** Two samples for the delamination test in order to determine, in accordance with DIN 53255, the bonding strength of the glue.

**10.5.2** Eight samples in accordance with DIN 53255 for the adhesive tensile lap-shear test to check the delamination test. Simple tensile lap-shear samples shall be used in accordance with Fig. 2.1.1.

**10.5.3** Six samples for the longitudinal strength test and six samples for the transverse strength test to determine the plywood tensile strengths in accordance with DIN 52377.

**10.5.4** Two kiln-dried samples for the determination of the moisture content of the plywood and the specific weight (apparent density) in accordance with DIN 52375.



**Fig. 2.1.1** Typical representation of a 3-ply longitudinal and a 5-ply transverse tensile lap-shear sample

## 10.6 Pre-treatment and testing of the samples

### 10.6.1 Glue bonding strength samples

**10.6.1.1** Two delamination samples and eight tensile lap-shear samples are used for testing the bonding strength of the glue.

**10.6.1.2** Before testing, these samples shall be subject to a boiling/drying alternation test and a short-time test BFU 100 in accordance with DIN 68705 and shall satisfy the test conditions of 10.6.1.3.

**10.6.1.3** Storage of the samples in boiling water with intermediate drying at 60 °C in the following cycle:

- 4 hours boiling
- 16 hours drying
- 4 hours boiling
- 2 hours cooling under water at 20°C

**10.6.1.4** The two delamination samples shall be subjected to a delamination test after this pre-treatment. The bonding shall offer considerable resistance to the forceful delamination of the veneers by means of a delamination tool, and the fracture area shall exhibit wood fracture and flawless bonding (cf. fracture diagrams DIN 53255).

**10.6.1.5** The eight tensile lap-shear samples shall be tested in a wet condition in the testing machine and shall satisfy the following minimum values:

For timber of the strength group F1:  
at least 1,5 N/mm<sup>2</sup>

For timber of the strength group F2:  
at least 1,2 N/mm<sup>2</sup>

### 10.6.2 Plywood strength test

**10.6.2.1** The six longitudinal tensile-strength samples and the six transverse tensile-strength samples shall undergo acclimatization prior to testing in the testing equipment and their moisture content shall be adjusted to 12 – 15 %.

**10.6.2.2** From each of the six samples, three longitudinal and three transverse samples shall be tested in the testing machine and the average strength value determined for these three samples.

**10.6.2.3** The two batches of three remaining samples serve as replacement samples for those samples which exhibit fractures at the clamping device with insufficient values. The fractured samples are then not to be used for evaluation purposes.

**10.6.2.4** The samples shall have the minimum plywood strengths as specified in [Table 2.1.2](#).

**10.6.2.5** Plywood made from other types of timber shall be included in the strength group with which its properties comply.

**10.6.2.6** If the production and the plywood strength at a manufacturing shop is continually monitored by GL and if the determination of the plywood strength of individual test batches is considered to be irrelevant, then the inspection and determination of the plywood strengths of these test batches can be waived.

**10.6.2.7** If plywood panels of the timber and strength group F1 do not achieve the required minimum plywood strength values of this group, then these panels can be assigned to the plywood strength group F2 and stamped accordingly.

**10.6.2.8** All boatbuilding plywood panels which are manufactured according to special specifications and conditions of the customers, or which deviate from GL regulations, are stamped according to their plywood type and strength group. The deviations or special features of such plywood panels shall be recorded in the test certificate.

### 10.6.3 Moisture test

**10.6.3.1** The two kiln-dried samples are used for determining the moisture content of plywood. They shall be examined in accordance with DIN 52375. The moisture content of the plywood should be 5 – 12 % ex works.

**10.6.3.2** Measurements of the moisture content of plywood by means of electrical measuring instruments can only be approved if check measurements using the kiln-dried samples have shown approximately identical values.

### 10.6.4 Determination of specific weight

**10.6.4.1** For the determination of the specific weight of the plywood panels, the two kiln-dried samples shall be measured and weighed as precisely as possible in dry-air conditions before the kiln-drying.

### 10.6.5 Inspection of the plywood scarf jointing

**10.6.5.1** The plywood scarf jointing shall be carried out in accordance with the conditions specified in [E.2](#), and bonded with glues approved by GL ([B.2](#).) under pressing power and pressing temperature without any flaws. The bonding of the scarf joint shall be checked by bending the panels over a test frame or a roller. If the scarf joints appear to be of doubtful quality, then this bending test shall be performed for both sides of the panels.

**10.6.6 Additional tests**

**10.6.6.1** If for any reason the GL surveyor has any doubts regarding the production and in particular the bonding of the plywood panels and its scarf jointing, then he shall be entitled to subject the test batch to additional tests of his choice, e. g. prising-open tests, knocking-off tests, bending tests, warping tests, soaking tests etc.

**11. Marking and stamping**

**11.1** All boatbuilding plywood panels inspected by GL surveyors and found to be in order shall be provided with the following stamping to identify the plywood type, grade and production:

- Stamping by the manufacturer:
  - Sign or mark of the manufacturing shop
  - Size and thickness of the panel

The plywood thickness is given in mm, the length and width of the panel in cm. The first dimension indicates the length of the panel in the longitudinal fibre direction of the outer layers.

  - Timber used for the outer and inner layers (separated by a dash).
  - Bonding type: "BFU 100"

The panels may be stamped neutrally, i. e. without the manufacturer's details, if explicitly so required by the customer.

- Stamping by Germanischer Lloyd:
  - A rectangular GL stamp, with the following details:
  - Boatbuilding plywood
  - Plywood grade I (or II)
  - Germanischer Lloyd
  - Testing date
  - A GL roller stamp along the end of panel with the identifying grade I or II and the testing date. The strength group F1 or F2 is applied by the same roller stamp, but with the addition "F1" or "F2" below the date.

As a rule, the stamping should be applied on the bottom right of that side of the panel which is of lesser quality (i. e. on the back).

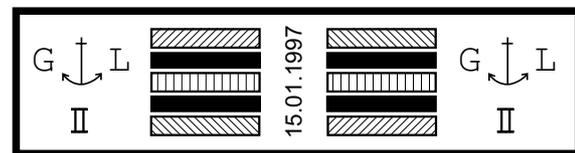
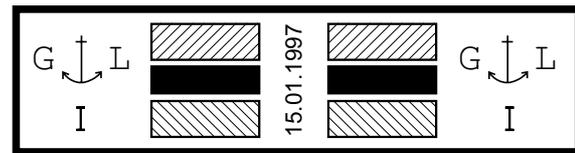
**11.2** In the case of long scarf-jointed panels, the GL stamp shall be made on both ends of the panel.

**11.3** Since inspection is only carried out randomly, the inspector is entitled to reject panels which have already been stamped, if they should prove to be defective.

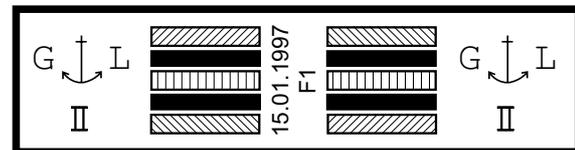
**11.4** The stamps have the following appearance, for example:

Manufacturer stamp:	GL-stamp:
Mark of the shop 250 × 122 × 6 Macoré – Macoré Rotary veneer Rotary veneer BFU 100	Boatbuilding plywood Grade I (or II) Germanischer Lloyd 15.01.97

Roller stamp to identify the grad:



Roller stamp to identify the strength group:



**12. Certificates**

**12.1** Germanischer Lloyd issues certificates for boatbuilding plywood panels which have been tested and approved, and these certificates are given to the manufacturer or customer.

**12.2** The certificate shows, among other things, the plywood types, the number of plywood panels inspected, the stamp and, if requested, the average values of the test results.

**13. Storage of the plywood panels**

**13.1** Finished plywood panels which are placed in storage shall be kept in closed rooms and stored horizontally.

**13.2** The plywood panels shall only be placed in horizontal stores that are at least 30 cm above the ground and from the walls, in order to avoid the effects of moisture.

**13.3** The individual stacks shall be protected against moisture from one side by covering panels.

13.4 Non-compliance with these storage regulations can lead to previous tests being declared invalid.

**D. Plywood for Aircrafts**

**1. General**

1.1 The testing of aviation plywood for aircrafts has been carried out by Germanischer Lloyd since 1931 and is valid for waterproof and boilproof plywood to be used for aviation purposes.

1.2 The plywood consists of at least three transversely veneer layers (Table 2.1.3). The bonding is with curable synthetic resin adhesives. The resistance of the adhesives to water and weather shall be demonstrated by long-term and outdoor testing.

1.3 Independent of the testing by Germanischer Lloyd, the manufacturer is obliged to continually carry out his own shop-based quality control of all working steps, the selection of the wood and its processing during production of the plywood panels.

1.4 The points listed under B.2 shall be taken into account.

**2. Structure**

2.1 The selection of the timber and the structure of the panels (number of veneer layers) shall be appropriate for the field of application.

2.2 The veneer layers shall be symmetrical around the middle layer, both with respect to the grain as well as to the thickness of the layers.

2.3 The thicknesses shall be selected in such a way that, as far as possible, the same strength is ensured in the longitudinal and lateral direction. GL reserves the right to exclude any panels with an unsuitable structure from the testing.

2.4 The following table gives a list of the required minimum number and thickness of the veneer layers:

**Table 2.1.3: Minimum number and thickness of the veneer layers**

Plywood thickness [mm]	Minimum number of veneer layers	Remarks
Up to 2	3	No layer shall be thicker than 2 mm.
From 2 to 6	5	
From 6 to 14	7	
Over 14	≥ 9	

2.5 Birch, beech, alder, okumé (gaboon) or other timber may be used, provided that the properties of the respective timber strength group are ensured.

2.6 Only binding agents (adhesives) authorized by GL may be used (cf. B.2).

**2.7 Surface treatment**

2.7.1 The panels may be manufactured as unsanded, lightly sanded, scoured, smoothed, resined or unresined.

2.7.2 The outer layers shall still be thick enough after processing so that reliable subsequent processing is ensured.

**3. Veneer joints**

3.1 Unless otherwise agreed between contractor and manufacturer, panels bonded with synthetic-resin adhesive may have veneer joints parallel to fibre direction in the middle and outer layers.

3.2 The joints shall be sealed perfectly and shall bond the veneers to each other by butt joints. The joints shall be glued on a suitable joint bonding machine.

3.3 The joints of the various veneer layers shall be staggered.

3.4 The strips of veneer of the outer layers shall be put together so that they match with regard to timber and colour.

3.5 Paper or plastic adhesive strips may not be used to secure or repair inner veneers layer.

3.6 Metal clamps used for securing purposes may only be positioned on the edges of the panels. They shall on no account remain on the panels when they are cut to standard dimensions.

#### 4. Strength groups

4.1 With regard to their suitability for the production of aviation plywood, the timbers listed below are currently approved; these have been divided into two strength groups.

Table 2.1.4: Strength groups

Timber	Strength group	Mean tensile strength of plywood MPa		
		Longitudinal	Transverse	Long. + transv. (added)
Birch	F1	≥ 70	≥ 45	≥ 140
Beech		≥ 70	≥ 45	≥ 140
Alder		≥ 70	≥ 45	≥ 140
Okumé (Gaboon)	F2	≥ 45	≥ 30	≥ 90
Poplar		≥ 45	≥ 30	≥ 90

4.2 In the case of panels over 3 mm thick, these values may be reduced by a maximum of 10 %.

4.3 Other types of wood may only be used for making plywood panels upon agreement with GL. The manufacturer shall always remain responsible for the correct selection of the quality and type of wood.

#### 5. Plywood grades

5.1 Plywood of the two strength groups is subdivided into two grades after inspecting its external and internal quality. In relation to their respective groups, grades I and II are identical with regard to type of wood, strength, production and bonding. They differ insofar that the panels of grade I can be used completely, while the panels of grade II are restricted to partial use because of local manufacturing defects or timber flaws.

5.2 The defects of grade II shall be limited to one third of the panel area. Two thirds of the panel shall be free of defects and suitable for use. The defects are identified during inspection by marking.

5.3 The visible side of the plywood panel shall be manufactured virtually without any defects and, furthermore, the quality, colour and grain shall be combined in such a manner that they match. The hidden-surface may have small colour differences or slight blemishes which do not influence the strength of the panel.

#### 6. Defects

6.1 The following wood and production defects are not permissible in the outer and inner veneer layers:

- Loose, mouldering knots, rotten knots, holes in the middle layers
- Firm knots over 6 mm diameter
- In the case of three-ply panels, more than four knots in one layer of a 100 × 100 cm large panel
- A distance of less than 200 mm between the knots.
- In the case of five- or multi-ply panels, more than six knots in one layer and less than 150 mm distance between the knots.

If the panel sizes are different to those specified above, the number of the permissible knots changes in accordance with the area. Knots up to 30 mm from the edge do not have to be taken into consideration.

- Short-grained, curly-grained and cross-grained wood, variegated appearance and discolourations, and mould stains if they decrease the strength and bending capability significantly.

Small signs of mould stains as well as bark specks do not have to be taken into consideration.

Short-grained or curly-grained wood covers such wood whose grain is interrupted and which has different growth directions (see photo, DIN 68256).

- Knot and shake scars and intergrown knots (see photo, DIN 68256).

Furthermore, the following manufacturing errors are not allowed:

- Joints which transgress the defined type, and inserted pieces (shims)
- Unbonded, open and badly closed joints
- Folds and shakes, breaks, peeling defects and bubbles as well as other such defects which decrease the strength of the panel. Up to three instances of damage, folds or shakes less than 30 mm from the edge of the panel do not have to be taken into consideration if they are not on opposite sides of the panel.
- Corrugated or bent panels
- Areas without binding agent, e.g. damage to the film of glue, insofar as these areas were not covered
- Heavy glue bleeding on more than one side of a panel.

## 7. Testing

### 7.1 General

**7.1.1** In general, the finished plywood panels are tested and approved at the manufacturing shop by an surveyor of Germanischer Lloyd.

**7.1.2** The inspection of finished plywood panels outside of the manufacturing shop is carried out by GL only by way of exception and under stricter testing conditions.

**7.1.3** GL reserves the right to also monitor the production of the plywood panels in the manufacturing shop.

### 7.2 Inspection of the plywood panels

**7.2.1** With respect to structure, and in particular bonding, all plywood panels are examined by GL and carefully tested after their completion by a GL surveyor. The panels are assigned, depending on the plywood type and quality, to the appropriate plywood strength group and grade. They are then graded and provided with the appropriate group and grade stamp.

**7.2.2** The plywood panels submitted to GL for inspection shall be examined, pre-graded, finished and then divided into test batches or orders by the manufacturer prior to GL inspection. Panels with faulty gluing are examined more closely to determine whether they are only limited locally or are present over the whole panel. If the latter is true, the entire test batch is tested with special care. If there are several such panels in a test batch, then the entire batch is rejected. If leaky joints or blocking cracks are found at the plywood edges of the inner layers, then these defects shall not be plugged before the GL inspection and decision of the GL surveyor as to whether these defects can be corrected, or whether the panel shall be rejected or assigned to grade II.

### 7.3 Grading of the plywood panels

**7.3.1** Grading the panels shall be in accordance with the differences between grades I and II specified in D.6. The panels are marked with the appropriate grade stamp.

### 7.4 Sampling

**7.4.1** For the inspection of the plywood panels, test panels are taken from the test batch submitted for inspection and provided with a sample number.

**7.4.2** Test pieces of approx. 25 cm length and 100 cm width are removed from these sample panels and provided with the sample number of the test panel.

**7.4.3** From these test pieces, the required samples are prepared and again provided with the sample number of the test panel.

**7.4.4** If only a few panels of a particular plywood type, or very thick and large panels, are submitted for inspection, and if the effort involved in cutting these panels appears to be too great, then samples can also be taken from pieces cut off the edge of these panels. For this purpose, it is necessary, when trimming these panels, to put the edge cuttings aside.

**7.4.5** The number of test panels is determined according to the following factors:

**7.4.5.1** If continuous inspections by GL in the manufacturing shop show that the production of the plywood panels appears to be reliable, and if the production is monitored continuously by suitable, automatic facilities or supervision, then it is not necessary to take test panels from each test batch.

**7.4.5.2** It is sufficient to select approximately 2 % (by number) of the panels from the current production to be used as samples.

**7.4.5.3** It shall be ensured that test panels cover all plywood thicknesses and types.

**7.4.5.4** If production problems occur, or if the GL surveyor has the impression that the production is not always reliable, then the surveyor can insist on the selection of a greater number of test panels.

**7.4.6** If one or several test panels should exhibit inadequate values during the inspection, then an additional two panels from the same test batch shall be tested. If, once again, the minimum requirements are not satisfied during this inspection, then the complete test batch shall be rejected.

### 7.5 General quality of the panels

**7.5.1** The general quality at the panels shall be determined by an external examination.

**7.5.2** The internal quality shall be examined against the light provided by a suitable source of illumination of sufficient intensity in a well darkened room.

**7.5.3** All panels up to a thickness which allows examination against light shall be subject to this inspection:

- Light timber, e.g. birch: up to 3,0 mm thickness,
- Darker timber, such as beech or okumé (gaboön): up to 1,5 mm thickness.

### 7.6 Thickness deviations

Deviations in production, especially with regard to the thickness, shall comply with the requirements of the

customer. If no other specifications exist, then the values listed in B.2 shall be used.

**7.7 Moisture test**

**7.7.1** Two kiln-drying samples are used for determining the moisture of plywood. This shall be done in accordance with DIN 52375. The moisture content of the plywood should be 5 – 12 % ex works.

**7.7.2** Measurements of the moisture content of plywood by means of electrical measuring instruments can only be approved if check measurements using the kiln-dried samples have shown approximately identical values.

**7.8 Tensile strength**

**7.8.1** The strength of at least three samples parallel to and three samples at right angles to the fibre direction of the outer layers of each test panel shall be determined by means of tensile testing in a calibrated testing machine.

**7.8.2** The tensile strength shall be determined in accordance with DIN 52377, using the test pieces specified therein.

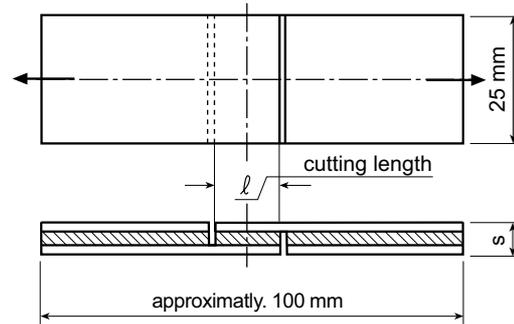
**7.8.3** The average value of the results for the same test panel is taken as the result of the test.

**7.9 Tensile lap-shear test**

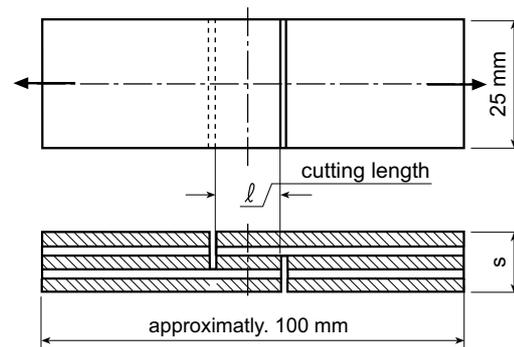
**7.9.1** The tensile lap-shear test shall be carried out in accordance with DIN 53255.

**7.9.2** The tensile lap-shear strength shall be determined with at least five samples from each test panel in a wet condition by shearing off the bonded area in a calibrated testing machine, as well as with two boiling samples of 10 cm × 10 cm dimensions:

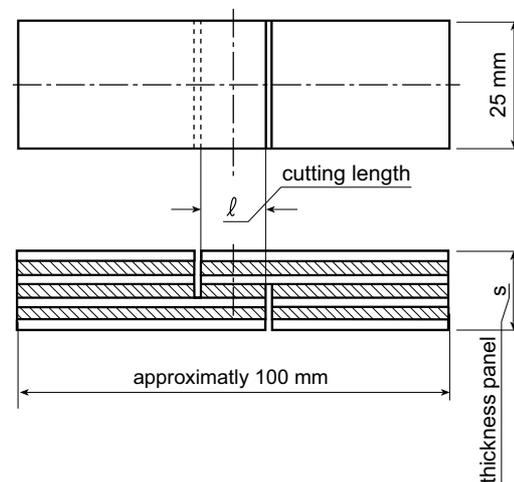
- Samples for 3-ply panels in accordance with Fig. 2.1.2
- Samples for 5-ply panels in accordance with Figs. 2.1.3 and 2.1.6
- Samples for 7-ply panels in accordance with Figs. 2.1.4 and 2.1.7
- Samples for 9-ply panels in accordance with Fig. 2.1.5.



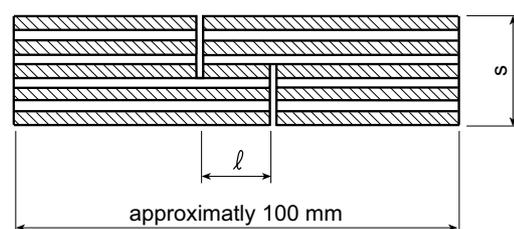
**Fig. 2.1.2** Longitudinal sample for a 3-ply plywood panel



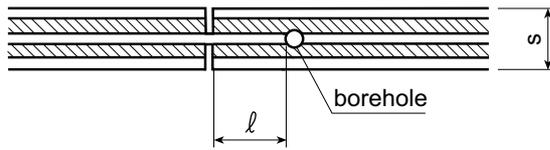
**Fig. 2.1.3** Transverse sample for a 5-ply plywood panel



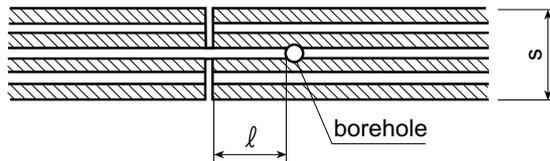
**Fig. 2.1.4** Longitudinal sample for a 7-ply plywood panel



**Fig. 2.1.5** Transverse sample for a 9-ply plywood panel



**Fig. 2.1.6 Longitudinal sample for a 5-ply plywood panel**



**Fig. 2.1.7 Transverse sample for a 7-ply plywood panel**

**7.9.3 Recommended values for the routing lengths of the adhesive samples**

The tested bonding area shall be small enough so that no wood shake occurs, and on the other hand shall be large enough so that the layers do not detach themselves too easily. See Table 2.1.5 for recommended lengths.

**7.9.4** Adhesive samples of 5-ply and multi-ply panels having thin veneer thickness which cannot, or cannot easily, be penetrated in accordance with Figs. 2.1.6 and 2.1.7, shall be prepared in accordance with Figs. 2.1.3, 2.1.4 and 2.1.6; however, the fibres of the outer layers shall be in the transverse direction in the case of 5-ply panels, and parallel to the longitudinal direction of the sample in the case of 7-ply panels. Routing of three or four layers shall be performed on each side.

**7.9.5** The samples shall have been immersed in water prior to the test for a sufficient period of time to ensure complete soaking.

Recommended values for soaking at room temperature (15 – 20°C):

- 24 hours for samples up to 2 mm thickness
- For thicknesses greater than 2 mm, the required time is determined by linear extrapolation.

Soaking of the samples may be substituted by three hours of boiling (three-hour immersion in boiling water).

**7.9.6** The strength after soaking or after boiling of the samples should be determined in a wet state and shall be at least 2 N/mm<sup>2</sup>.

**7.9.7** Isolated values may be up to 10 % below this requirement.

**7.9.8** In addition, a three-hour boiling test shall be performed twice on two 10 cm × 10 cm samples from each test panel. The samples shall be first boiled for three hours in water and then dried at 60 °C. After this, they shall again be boiled for three hours, cooled in warm water for two hours at 20 °C and then, in a wet state, shall either be manually or with suitable equipment bent several times back and forth until they break. In doing so, there shall be no sign of loosening of the individual veneer layers, no embrittlement or unfavourable appearance of the glue joint.

**7.9.9** If the GL surveyor notices anything unusual in this respect, he shall then increase the number of the tests and carry them out on the panels in question.

**7.9.10** In the case of bonding with phenolic resin, boiling tests may be omitted at the discretion of the GL surveyor.

**7.10 Additional tests**

**7.10.1** If the GL surveyor has any doubts regarding the production and, in particular, the correct bonding of the plywood panels and its scarf jointing, then he is authorized to subject the test batch to additional tests. For example: prising-open tests, knocking-off tests, bending tests, warping tests, soaking tests etc.

**Table 2.1.5**

Panel thickness = s in mm	up to 0.8	1 – 2	2.5	3	4	5	6	8	10 – 14	16 – 20
Cutting length = l in mm	3	4	5	5	6	7	8	9	10	12
Glue surface for the samples acc. Fig. 2.1.2, 2.1.3, 2.1.4 and 2.1.5								= cutting length	1 × width of sample,	
Glue surface for the samples acc. Fig. 2.1.6 and 2.1.7								= 2 × cutting length	1 × width of sample.	

## 8. Marking and stamping

8.1 Each panel which satisfies this Regulation and is approved shall be provided with the following stamp:

8.1.1 Stamping by the manufacturer:

- Sign or mark of the manufacturer
- Thickness of the panel in mm and the timber used
- Letters which identify the type of bonding e.g.
  - T = bonded with Tego film
  - PH = bonded with phenolic resin
  - M = bonded with melamine resin
  - R = bonded with resorcinol resin

As an alternative, the type of bonding can be identified by "BFU 100".

8.1.2 Stamping by Germanischer Lloyd:

- A stamp that identifies the grade GL I or II, the number of the test batch, the year of testing, e.g. "2 - 26/96" (test batch 2 of the 26th week in 1996).
- The stamps should be applied by means of a roller stamp diagonally across the panel on the side of lesser quality.

8.2 Since inspection is only carried out randomly, the surveyor is entitled to reject panels which have already been stamped, if they should prove to be defective.

8.3 GL is entitled to stop providing stamps if production defects occur continually.

## 9. Certificates

9.1 Germanischer Lloyd issues certificates for tested and approved plywood panels, and these certificates are handed over to the manufacturer or customer.

9.2 The certificate specifies, among other things, the plywood type, the number of plywood panels inspected, the stamping and, if requested, the average values of the test results.

## 10. Storage of the plywood panels

10.1 Finished plywood panels placed in storage shall be kept in closed rooms.

10.2 The plywood panels shall only be placed in horizontal stores that are at least 30 cm above the

ground and from the walls, in order to avoid the effects of moisture.

10.3 The individual stacks shall be protected against moisture from one side by covering panels.

10.4 Non-compliance with these storage regulations can lead to previous tests being declared invalid.

## E. Joining of Wood Materials

### 1. Laminated and multilayered components

1.1 In order to reduce variations in the characteristic values of wood and therefore to arrive at reasonable safety factors to be applied in designing structural elements, the wood is homogenized by means of lamination. Laminated components are bonded components consisting of individual layers (at least three) of sawn timber which have the same grain direction.

1.2 Multilayered components are bonded components in which the individual layers (at least three) consist of sawn timber and have different grain directions. The thickness of the individual laminates depends on the shape of the components to be laminated. However, the laminate thicknesses should not, if possible, be less than 5 mm and should not exceed 25 mm in the case of curved parts. In the case of straight parts, the laminate thickness should not be more than 40 mm.

1.3 Adhesives may only be used that are resistant to cold and boiling water and that in the bonded joint have the same strength as that of the wood (see also C. and D.). A precondition for the carrying out of gluing procedures is the availability in the workshops of temperature and humidity controls as well as clamping facilities.

1.4 The moisture of the wood should be 12 – 15 % at the time of bonding; but must not exceed 18 %. Efforts should be made to keep the glued joint as thin as possible (0,1 – 0,2 mm).

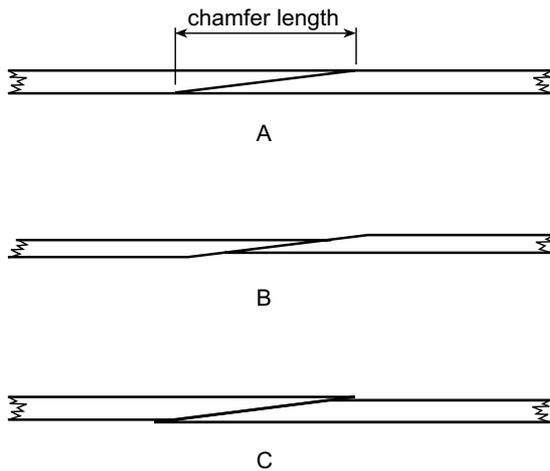
1.5 Since transverse compressive stresses during subsequent swelling of the wood are less damaging than transverse tensile stresses brought about by subsequent volume contraction, it is recommended that the timber be dried to an average moisture content that is the same as, or just below, the average moisture content of the component,

1.6 If adhesives on a formaldehyde basis are used (e.g. for boatbuilding timber), then a pre-drying time for the moist joining surface for 5 – 10 minutes may be necessary to enable low-molecular substances to escape.

1.7 Sufficiently long clamping times shall be adhered to, depending on the bonding temperature. In the case of curved or welded parts, the clamping time shall be extended accordingly.

**2. Scarf jointing**

2.1 The joint ends shall be precisely joined in order to avoid faulty gluing or other defects.



**Fig. 2.1.8 Scarf joints across the thickness**

2.2 Fig. A illustrates the correct method. Fig. B depicts the incorrect method; it is especially unsuitable, as faulty gluing occurs frequently because of insufficient pressing power. The method illustrated in Fig. C is also wrong and causes a variety of defects. In this case, particularly when sanding plywood panels down until they are smooth, the outer layers are sanded away excessively.

2.3 The minimum pressing power shall not fall below 4 kg/cm<sup>2</sup>.

2.4 Glued scarf-jointing of solid wood shall have a chamfer length which is eight times the panel thickness.

2.5 For glued scarf-jointing of plywood, the ratio of the plywood thickness to chamfer length shall be as follows:

- For panels up to 10 mm:  
at least 1:10
- For panels over 10 mm:  
at least 1:8

2.6 Further information is given in the VG 81243 Standard (Wood Bonding in Wood Boatbuilding).

**F. Wood Protection**

1. All timber (with the exception of the timber of the durability group I, Table 2.1.2) shall be protected by several coats of suitable protective paint, or by means of impregnation with a proven wood preservative, against fungi and insect infestation. Impregnation is the preferred method for interior surfaces of the boat's components which are exposed to water or weather (outer e. g. skin, deck, superstructure) and which have received a coat of paint impervious to vapour pressure.

2. All plywood parts shall be protected by several coats of paint or varnish. Special attention shall be paid to plywood edges and drill-holes by pretreating them with recognized and proven edge protection coatings.