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**Large yachts — Strength, weathertightness and watertightness of glazed openings —**

**Part 2:  
Glazed opening integrated into adjacent structure (elastically bonded to bulkhead or shell) design criteria, structural support, installation and testing**

*Grands yachts — Résistance, imperméabilité au mauvais temps et étanchéité des ouvertures vitrées —*

*Partie 2: Critères de conception, support structurel, installation et essais des ouvertures vitrées faisant partie intégrale de la structure adjacente (directement collées sur la cloison ou le bordé)*

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Published in Switzerland

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 12, *Large yachts*.

A list of all parts in the ISO 11336 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

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# Large yachts — Strength, weathertightness and watertightness of glazed openings —

## Part 2:

# Glazed opening integrated into adjacent structure (elastically bonded to bulkhead or shell) design criteria, structural support, installation and testing

## 1 Scope

This document specifies technical requirements for direct adhesive bonding of glazing materials into recesses forming part of the structure of the ship and into frames that are fastened to the structure of the ship.

It is applicable to large yachts as defined in ISO 11336-1.

This document is limited to the bonding of independent glazed openings, where the bonded joint is designed to withstand local loads (from external loads coming from weather and sea conditions, internal impact loads from accidental passenger or cargo shifting, wind suction and accelerations due to ship motions).

Bonding of glazed openings where the glazing material is subjected to loads from global ship motions (bending, shear force and torsion), which are considered as structural glazed openings, are outside the scope of this document. Quantitative identification of the global deflection is also outside the scope.

Additionally, this document is limited to bonding that exhibits elastic behaviour, and excludes rigid bonding and nonlinear elastic bonding.

The design of the bonding for the following installation types is outside the scope of this document:

- fire protected areas;
- glazed bulwarks;
- underwater glazing;
- pool glazing;
- glazing for use in polar areas;
- unstepped IGUs.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 48-5, *Rubber, vulcanized or thermoplastic — Determination of hardness — Part 5: Indentation hardness by IRHD pocket meter method*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 8339, *Building construction — Sealants — Determination of tensile properties (Extension to break)*

ISO 11003-1, *Adhesives — Determination of shear behaviour of structural adhesives — Part 1: Torsion test method using butt-bonded hollow cylinders*

ISO 11003-2, *Adhesives — Determination of shear behaviour of structural adhesives — Part 2: Tensile test method using thick adherends*

ISO 11336-1:2012 *Large yachts — Strength, weathertightness and watertightness of glazed openings — Part 1: Design criteria, materials, framing and testing of independent glazed openings*

DIN 53504, *Testing of rubber — Determination of tensile strength at break, tensile stress at yield, elongation at break and stress values in a tensile test*

DIN 6701-3:2015, *Adhesive bonding of railway vehicles and parts. Part 3 Guideline for construction design and verification of bonds on railway vehicles*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

#### 3.1 bonding material

adhesive material that is used to adhere or bond items together

#### 3.2 bonding process

process to join two materials with an adhesive

#### 3.3 bonded joint

joint between the *glazing* (3.6) and substrate, consisting of a *bonding material* (3.1) and a *sealing material* (3.4) if required

#### 3.4 sealing material

material used to cover and protect (where necessary) the *bonding material* (3.1)

Note 1 to entry: The sealing itself is not considered to be part of the adhesive bond.

Note 2 to entry: The following items can have a negative effect on bonding materials:

- UV Light,
- seawater,
- chemicals (from cleaning compounds and or biological degradation).

Unless the bonding is specifically designed to be resistant to the above items, it must be protected by a seal or *sealing material* (3.4). The sealing material (if present) combines with the bonding to form a weather or watertight seal.

### 3.5 elastic bonding

bonding where the *bonded joints* (3.3) are capable of transferring forces and distributing stresses evenly and show a high degree of flexibility (ability to return to its original shape after deformation)

Note 1 to entry: Its purpose is to hold the *glazing* (3.6) in place, and to maintain its attachment to the structure (transmitting loads from the glazing to the ship's structure). Additionally, it provides the watertight/weathertight boundary, whilst allowing rotational deflection and expansion/contraction of the glazing and/or the supporting structure.

### 3.6 glazing

transparent or translucent pane

### 3.7 glazed opening

opening in the hull, superstructure or deckhouse of a ship structure fitted with *glazing* (3.6)

### 3.8 independent glazed opening

*glazed opening* (3.7) where the mechanical behaviour of the pane can be considered independent from adjacent structures

EXAMPLE *Framed appliance* (3.9).

### 3.9 framed appliance

*independent glazed opening* (3.8) where the glass is clamped into a frame structure consisting of a frame and a mechanical retainer

Note 1 to entry: For a framed appliance, the weight of the glass is mainly kept by the frame and the retainer. A rubber gasket or an adhesive is used in this construction to prevent the direct contact between glass and frame and to achieve watertightness or weathertightness.

### 3.10 appliance

device made of *glazing* (3.6) and adhesive or frame, used to cover and protect an opening in the hull, superstructure or deckhouse

### 3.11 glazed opening integrated into adjacent structure

*glazed opening* (3.7) where the mechanical behaviour of the pane cannot be considered independent from adjacent structures

EXAMPLE Pane bonded directly into a frame.

### 3.12 insulated glazing unit IGU

*glazing* (3.6) made of multiple panes, either monolithic or laminated, separated by sealed gaps filled with gas (air, argon, etc.)

### 3.13 stepped IGU

*IGU* (3.12) where one of the panes is fixed to the framing while the other pane is not supported by the framing structure

Note 1 to entry: The bonding of stepped IGUs can be designed using the approach defined in this document.

Note 2 to entry: See [Figure 1](#).

3.14

**unstepped IGU**

IGU (3.12) where both panes are supported by the framing structure

Note 1 to entry: See Figure 1.

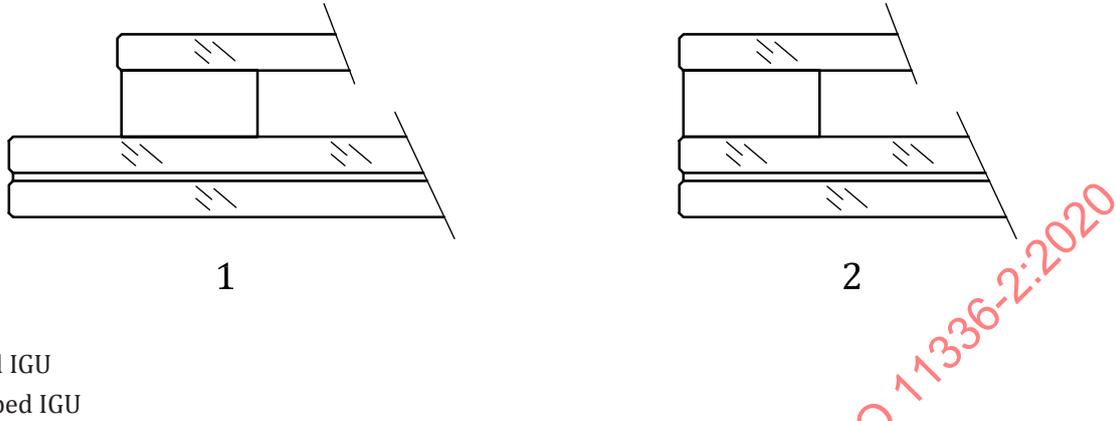


Figure 1 — Stepped and unstepped IGU glazing

3.15

**bonded window**

glazed opening (3.7) where the glass is attached to the adjacent structure by an adhesive

Note 1 to entry: For a bonded window, the adhesive holds the weight of the glass and keeps the glass in its position under load. Bonded windows can be used like a framed window in any position on board of a large yacht.

3.16

**substrate**

material from which the frame, hull or superstructure is constructed, which can include filler, primer, and paint systems

EXAMPLE Steel, aluminium, fibre reinforced plastic (FRP), or wood.

3.17

**surface preparation**

process of treating the surface of a substance in order to increase its adhesion, which includes applying components such as activators, cleaners and primers

3.18

**UV protection**

UV light blocking border, applied to the surface or within the laminate of the glazing, designed to protect the bond from UV light

3.19

**spacer**

element used to support the glass weight and to secure positioning during installation and bond cure, that is removed prior to the application of the sealing

3.20

**setting block**

element used to support the glass weight and to secure positioning during installation and bond cure, left in place throughout the lifetime of the bonding but considered not to take any load

Note 1 to entry: The setting block must be chemically compatible and must have a shore hardness less than the surrounding bonding and sealing.

**3.21  
resting pad**

element designed to support the glass weight and to secure positioning during installation, bond cure and during the lifetime of the bonding

Note 1 to entry: A resting pad is left in place throughout the lifetime of the bonding, and must be chemically compatible. It must have a shore hardness greater than the surrounding bonding and sealing, so as to support the glass weight throughout the lifetime of the bonding.

**3.22  
bonding width**

distance along the mating faces of the substrate and adhesive, and the adhesive and *glazing* (3.6)

Note 1 to entry: See [Figures 2](#) to [4](#) for illustrative sketches.

**3.23  
bonding thickness**

distance between the mating faces of the substrate and the glazing

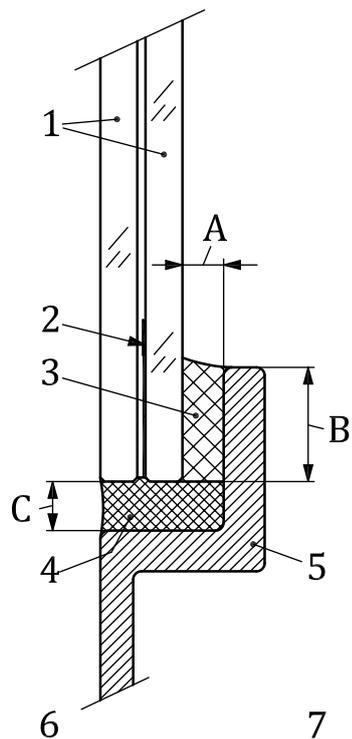
Note 1 to entry: See [Figures 2](#) to [4](#) for illustrative sketches.

**3.24  
sealing gap**

in case of flush or recessed glazing, distance between the edge of the glazing and substrate and/or adjacent glazing, measured in the plane of the glazing

Note 1 to entry: See [Figures 2](#) to [4](#) for illustrative sketches.

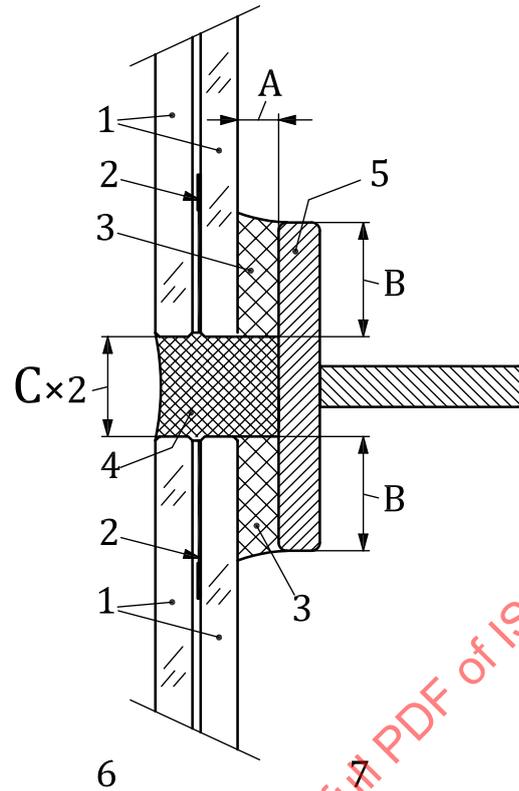
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**Key**

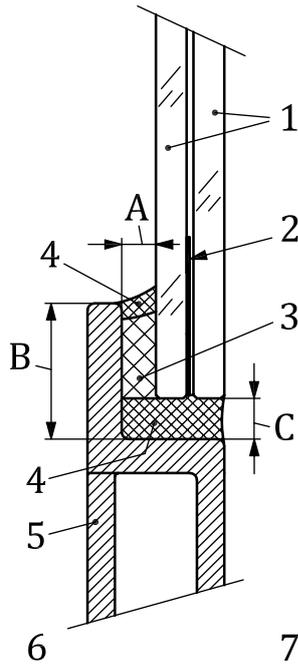
- 1 glazing
- 2 UV protection
- 3 bonding material
- 4 sealing material
- 5 substrate
- 6 outside
- 7 inside
- A bonding thickness, see [3.23](#)
- B bonding width, see [3.22](#)
- C sealing gap, see [3.24](#)

**Figure 2 — Bonding from outside — Glazing to substrate**

**Key**

- 1 glazing
- 2 UV protection
- 3 bonding material
- 4 sealing material
- 5 substrate
- 6 outside
- 7 inside
- A bonding thickness, see 3.23
- B bonding width, see 3.22
- C sealing gap, see 3.24 (note that for a glass to glass bonding, the seal gap is  $2 \times C$ )

**Figure 3 — Bonding from outside — Glazing to glazing and substrate**



**Key**

- 1 glazing
- 2 UV protection
- 3 bonding material
- 4 sealing material
- 5 substrate
- 6 outside
- 7 inside
- A bonding thickness, see 3.23
- B bonding width, see 3.22
- C sealing gap, see 3.24

Note For limits of the use of windows bonded from the inside, see ISO 11336-1:2012, 6.2.2.

**Figure 4 — Bonding from inside (see Note) — Glazing to substrate**

**3.25**

**bonding manufacturer**

competent entity that provides the *bonding material* (3.1) and *sealing material* (3.4), the technical documentation and the application guidance for its use by the bonding installer

**3.26**

**bonding installer**

company, organisation, or person responsible for the installation of the *glazing* (3.6), bonding, and sealing

**3.27**

**sloped glazed opening**

*glazed opening* (3.7) where the installation is such that the plane of the *glazing* (3.6) of the appliance is orientated at an angle to vertical

**3.28**

**overhead glazed opening**

*glazed opening* (3.7) where the installation of the appliance is located where persons on board can be underneath

**3.29****walkable glazed opening**

*glazed opening* (3.7) where the installation of the appliance is located in a position where persons can walk or stand on the opening during normal operations

**3.30****retainer**

structural or mechanical device that is fastened to the substrate and that prevents the glazing from falling out of the recess in the event of failure of the bonding material

**3.31****filler**

substance used to fill or fair the structure of a yacht prior to painting

**3.32****reduction factor**

factor used to take into account the effect of the reduced performance of an adhesive when exposed to a particular load (environmental) situation

Note 1 to entry: See 7.1 and 11.1.

**3.33****temperature exposure**

temperature range considered for the bonding likely to be experienced during the lifetime of the yacht

**3.34****permanent static load**

long duration load that does not change in magnitude

EXAMPLE *Self weight* (3.36).

**3.35****dynamic cyclic load**

short duration load that varies in cycles

EXAMPLE Wave or wind pressure, accelerations due to ship motions.

**3.36****self weight**

force exerted by gravity on a body

**3.37****aging conditions**

long term exposure to environmental conditions that can reduce the performance of a *bonding material* (3.1)

EXAMPLE UV, temperature.

**3.38****design pressure**

pressure acting on the *glazing* (3.6) due to the independent or combined actions of the wave impact and head of water

**3.39****wind load**

pressure or wind suction loads acting on the *glazing* (3.6) due to the movement of air

**3.40****linear thermal expansion**

change in linear dimension of a material in response to a change in temperature

3.41

**bonding application guidance**

guidance information, provided by the bonding manufacturer, for use of the *bonding material* (3.1) or materials during installation

3.42

**bonding installation procedures**

operational procedures, provided by the bonding installer, to detail and control the *bonding process* (3.2) during installation

**4 Symbols**

$\sigma_A$	Allowable strength, N/mm <sup>2</sup>
$\sigma_v$	Equivalent stress, N/mm <sup>2</sup>
$\sigma_{lab}$	Characteristic strength value at laboratory condition (95 % confidence), N/mm <sup>2</sup>
$\sigma$	Stress along bonding thickness direction (compression or tensile stress), N/mm <sup>2</sup>
$f_{redT}$	Reduction factor for temperature exposure
$f_{redS}$	Reduction factor for permanent static load
$f_{redD}$	Reduction factor for dynamic cyclic load
$f_{redF}$	Reduction factor for fatigue cyclic load
$f_{redA}$	Reduction factor for aging conditions
$S$	Material factor
$R$	Ratio compression strength to tensile strength of adhesive
$c$	Maximum allowable adhesive elongation, decimal fraction or percentage
$\gamma$	Shear strain
$P_D$	Design pressure, kN/m <sup>2</sup>
$P_{wind,max}$	Maximum wind load (dynamic load), kN/m <sup>2</sup>
$P_{wind,med}$	Medium wind load (fatigue load), kN/m <sup>2</sup>
$T_{design}$	Maximum/minimum design temperature of the window, °C
$T_{application}$	Temperature of joint application, °C
$a_{max}$	Maximum acceleration due to sea swell, m/s <sup>2</sup>
$a_{med}$	Medium acceleration due to sea swell, m/s <sup>2</sup>
$\alpha_g$	Linear thermal expansion coefficient of glazing material
$\alpha_s$	Linear thermal expansion coefficient of substrate material
$\tau$	Stress perpendicular to glass plane applied at the bonding surface - shear stress, N/mm <sup>2</sup>
$\tau_{Supp}$	Supported shear stress, N/mm <sup>2</sup>

$\tau_{\text{Unsupp}}$	Unsupported shear stress, N/mm <sup>2</sup>
$\beta$	Glazing angle, °
$d$	Bonding thickness, mm
$w$	Bonding width, mm
$C_{\text{gap}}$	Sealing gap, mm

## 5 Bonding materials

### 5.1 General

A record of the bonding application guidance (see 8.1) and bonding installation procedures (see 8.2) shall be provided and kept on board (see ISO 11336-3).

Where no previous information on the installed bonding is available and it is required to install new bonding, compatibility tests shall be made (see ISO 11336-3).

The bonding material shall meet the minimum requirements specified in 5.3.

The simplified and approximated structural model of the bonding, considered in this document, is made of two stress components: a uniaxial tensile or compressive component ( $\sigma$ ) perpendicular to the glass plane, and a shear component ( $\tau$ ) whose plane is perpendicular to the glass plane and applied at the bonding surface. This is shown in Figure 5.

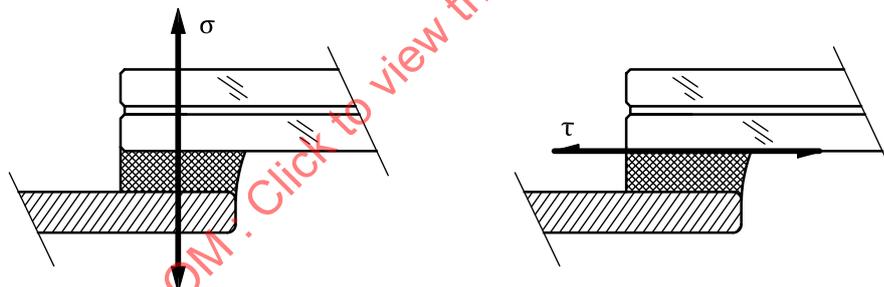


Figure 5 — Tensile or compressive ( $\sigma$ ) and shear ( $\tau$ ) stress components

### 5.2 Physical characteristics

#### 5.2.1 Flexural modulus

Tests according to ISO 37, ISO 527-1, ISO 527-2 and DIN 53504.

#### 5.2.2 Elongation

Tests according to ISO 37, ISO 527-1, ISO 527-2 and DIN 53504.

#### 5.2.3 Shear modulus

Tests according to ISO 11003-1 and ISO 11003-2, DIN 6701-3.

#### 5.2.4 Tensile strength

Tests according to ISO 37 and DIN 53504.

### 5.2.5 Shore hardness

Tests according to ISO 48-5.

### 5.2.6 Environmental resistance

The resistance of the bonding material shall be tested and documented by the manufacturer to ensure it is suitable for the intended purpose.

An alternative to this is the installation of a protective layer or sealing. The long-term suitability of this layer and/or sealing for protection shall be tested and documented.

### 5.2.7 Long term properties

Long term properties of the bonding material shall be tested and documented. These shall include:

- adhesion (to all substrate materials);
- cohesive strength;
- elasticity;
- creep;
- environmental resistance.

### 5.2.8 Preparation of bonding surfaces

The surface preparation of the substrate and glazing to be bonded shall be in accordance with the application guidance of the bonding manufacturer (see [8.1](#)).

### 5.2.9 Glazing material

The installer shall ensure that the bonding and sealing materials are compatible with the glazing material.

## 5.3 Minimum material properties

The bonding material shall have the following minimum material properties:

- |                                       |                          |
|---------------------------------------|--------------------------|
| — minimum tensile strength            | 0,70 N/mm <sup>2</sup> ; |
| — tensile stress at 12,5 % elongation | 0,14 N/mm <sup>2</sup> ; |
| — fracture elongation                 | 50 %.                    |

Testing/qualification shall be carried out in accordance with ISO 8339. The short- and long-term performance of the adhesion between the bonding material and the substrate shall be documented in the relevant load direction (tension, compression and shear).

## 6 Bonding arrangement

### 6.1 Glazing

The design of the glazing for a glazed opening (accounting for its location, design pressure, and scantlings) shall be developed as if considered as a framed window according to ISO 11336-1.

## 6.2 General

Bonding shall, in general, be in a recess designed to accommodate the glazing appliance, contained with an appropriate sealing gap and the required bonding thickness and width. The external edge of the glazing shall not protrude beyond the immediate surrounding surface (e.g. the filler, adjacent structure, or other glazing). The main motivation for this is to protect the edges of the glazing, bonding and sealing.

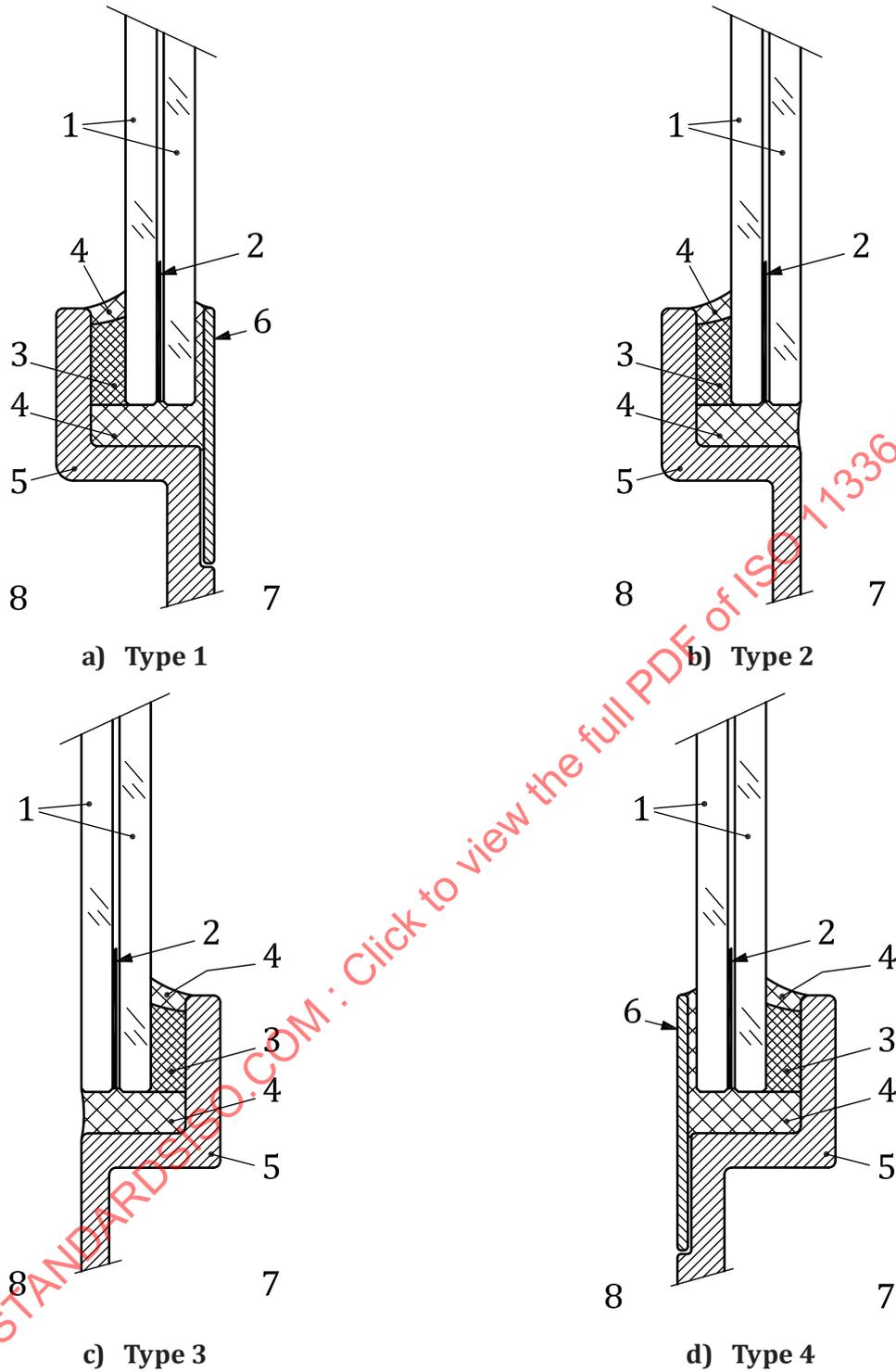
The global deflection of the structure of the vessel and the local deflection of the glazing panel can induce loads that shall be considered when designing the bond.

Contact between the glazing panel and the adjacent structure (or adjacent glazing) of the vessel under local pressure or thermal loads shall be avoided.

The dimensions of the bond shall also account for its elastic limit, and general production and installation tolerances of both the glazing and adjacent structure.

Typical arrangements for a number of bonding installations are shown in [Figure 6](#).

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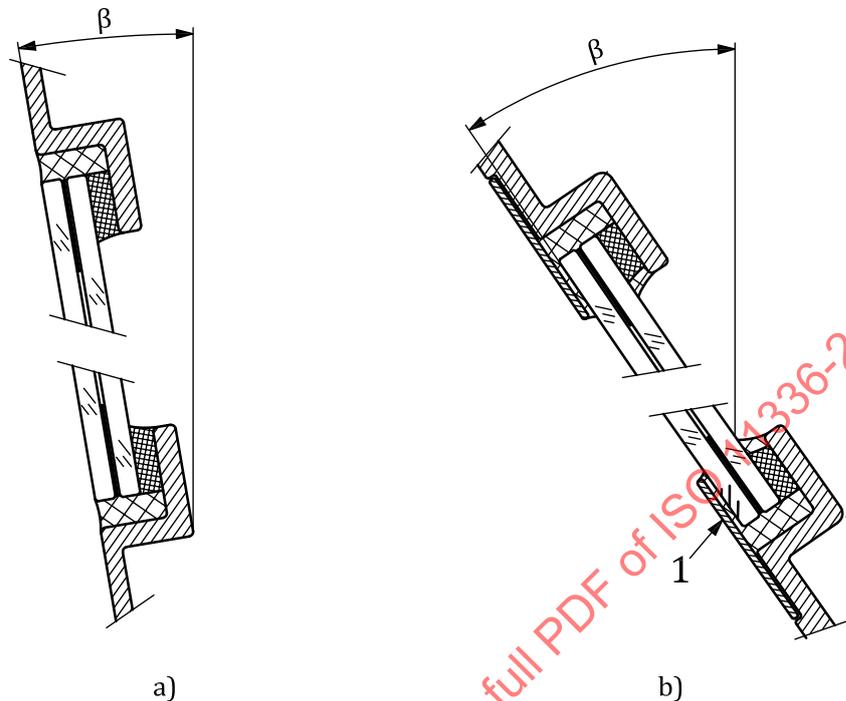
**Key**

- |                    |             |
|--------------------|-------------|
| 1 glazing          | 5 substrate |
| 2 UV Protection    | 6 retainer  |
| 3 bonding material | 7 inside    |
| 4 sealing material | 8 outside   |

**Figure 6 — Typical bonding arrangements**

### 6.3 Sloped and overhead glazed openings — Bonding in tension

Figure 7 shows typical arrangements of sloped and overhead glazing with the bonding in tension.



#### Key

- a) sloped – no retainer  $10^\circ \geq \beta > 0^\circ$
- b) sloped or overhead with retainer  $\beta > 10^\circ$
- 1 retainer

**Figure 7 — Sloped and overhead glazed openings**

For sloped glazed openings (angle to vertical,  $10^\circ \geq \beta > 0^\circ$ ) where the bond is in tension, the bonding shall be designed using the approach defined in [Clause 7](#).

For sloped and overhead glazed openings (angle to vertical,  $\beta > 10^\circ$ ), a retainer shall be provided. The retainer shall be designed to take the loads required to hold the glazing in place.

Overhead and walkable glazed openings shall be fitted with a mechanical retainer.

Overhead glazing can be exposed to different load cases, such as personnel loads, impact, etc. These load cases are considered outside the scope of this document, but the design of the bonding shall take them into account.

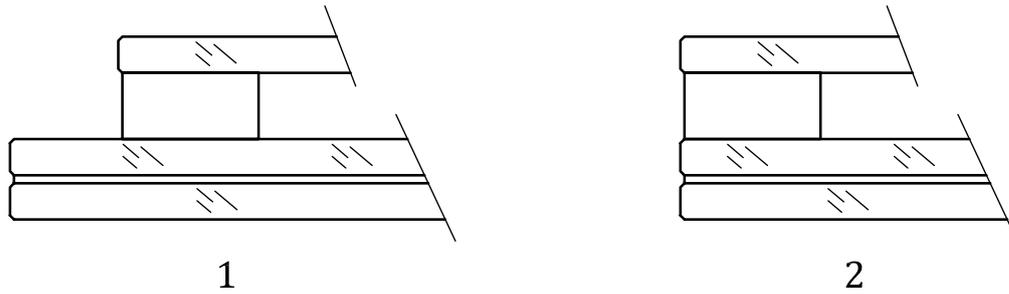
Where required, the mechanical retainer shall prevent the window from falling out in case of bonding failure. Design of the mechanical retention of the glazing shall take into account the installation and location.

### 6.4 Insulated glazed units (IGUs)

There are two key types of IGUs, stepped and unstepped, as shown in [Figure 8](#).

Bonding for stepped IGUs can be designed using the approach defined in this document.

Bonding for unstepped IGUs cannot be designed using the approach defined in this document, and are considered outside its scope.



**Key**

- 1 stepped IGU
- 2 unstepped IGU

**Figure 8 — Stepped and unstepped IGU glazing**

**6.5 Bonding limitations**

The design of the bonding for the following installation types is considered outside the scope of this document; they have specific requirements that should be considered on a case by case basis:

- fire protected areas;
- glazed bulwarks;
- underwater glazing;
- pool glazing;
- glazing for use in polar areas;
- unstepped IGUs.

For underwater glazing, pool glazing, and glazing for use in polar areas, [Annex D](#) provides some guidance.

**7 Bonded joint design**

This document considers the following types of load:

- environmental loads (water and wind pressure);
- self weight and inertial loads;
- internal (or none load side) impact;
- thermal expansion of glazing and structure.

In general, the approach in this document limits the design to applications where the bonded joint is stressed by tensile or compressive and shear components. Applications where peel or cleavage take place are outside the scope of this document. As mentioned in the Scope, this document is limited to bonding that exhibits elastic behaviour, and excludes rigid bonding and nonlinear elastic bonding. Design methods outlined in the below clauses are largely based on principles exposed in Reference [1].

Bonding that is considered outside the scope of this document should be considered on a case by case basis.

The bonded joint that is defined within this document assumes that there is sufficient adhesion of the bonding to the substrate. This should be validated in accordance with the bonding manufacturers

guidance, with the bonding procedure ensuring this process has been followed. ISO 11336-3 details quality requirements for the adhesion of the bonding to the substrate.

## 7.1 General

### 7.1.1 Overview

Design of bonded joints in terms of their structural integrity shall be considered by the comparison of the allowable strength ( $\sigma_A$ ) of the adhesive material to the equivalent stress ( $\sigma_v$ ) generated by the loading conditions of the adhesive joint (see Formula below).

The allowable strength ( $\sigma_A$ ) shall be determined from the characteristic strength value determined by testing in laboratory conditions at 95 % confidence limit ( $\sigma_{lab}$ ) and from the reduction factors  $f_{red,i}$  that take into account different strength reduction mechanisms. An additional design factor “S” may be considered to take into account additional reduction situations. The allowable strength shall be evaluated according to the following general Formula ( $i=1\dots N$  reduction factors):

$$\sigma_A = \frac{\sigma_{lab} \cdot f_{redT} \cdot f_{redS} \cdot f_{redD} \cdot f_{redF} \cdot f_{redA} \cdots f_{red,i}}{S}$$

The acceptable condition shall be:

$$\sigma_v \leq \sigma_A$$

The comparison of the allowable strength to the equivalent stress the resultant safety factor ( $S_i$ ) for each load case ( $i=1$  to  $n$ ) is:

$$S_i = \frac{\sigma_{A,i}}{\sigma_{v,i}} \geq 1$$

the adhesive material characteristics to be provided for the determination of the allowable strength ( $\sigma_A$ ) shall be:

Adhesive material characteristics (see [Clause 4](#)):

- $\sigma_{lab}$ , Characteristic Strength value at laboratory condition (95 % confidence);
- $f_{red,T}$ , Reduction factor for temperature exposure (70 °C);
- $f_{red,S}$ , Reduction factor for permanent static load;
- $f_{red,D}$ , Reduction factor for dynamic cyclic load (10,000 cycles);
- $f_{red,F}$ , Reduction factor for fatigue cyclic load ( $>10^7$  cycles);
- $f_{red,A}$ , Reduction factor for aging conditions.

$S$ , Additional material factor as described by the bonding manufacturer, otherwise  $S$  is 1.

$R$ , Ratio compression strength to tensile strength of adhesive.

$c$ , Maximum permitted adhesive elongation.

The maximum shear strain of the adhesive “ $\gamma$ ” can be expressed in terms of the maximum allowable adhesive elongation,  $c$  (see formulas below).

The above material characteristics shall be confirmed by the bonding manufacturer, refer to [Clause 11](#) for guidance.

The equivalent stress in load conditions ( $\sigma_v$ ) shall be determined on the basis of the load condition parameters.

Load conditions parameters:

- $P_D$  Design pressure, kN/m<sup>2</sup>;
- $P_{wind,max}$  Maximum wind load (dynamic load), kN/m<sup>2</sup>;
- $P_{wind,med}$  Medium wind load (fatigue load), kN/m<sup>2</sup>;
- $T_{design}$  Maximum/minimum design temperature of the window, °C;
- $T_{app}$  Temperature of joint application, °C;
- $a_{max}$  Maximum acceleration due to sea swell (m/s<sup>2</sup>);
- $a_{med}$  Medium acceleration due to sea swell (m/s<sup>2</sup>).

Other data to be provided are the linear thermal expansion coefficients of the materials involved in the bond line that is glazing material and substrate material (see [Figures 1, 2 and 3](#)):

- $\alpha_g$ , linear thermal expansion coefficient of glazing material;
- $\alpha_s$ , linear thermal expansion coefficient of substrate material.

The thickness of the bonding,  $d$  (mm), and the sealing gap,  $c_{gap}$  (mm), shall be calculated by considering the relative movement:

$$\Delta s = |(T_{design} - T_{app}) \cdot (\alpha_g - \alpha_s)| \cdot \sqrt{\left(\frac{H}{2}\right)^2 + \left(\frac{W}{2}\right)^2}$$

$$d = \frac{\Delta s}{\gamma}$$

$$\gamma = \frac{\Delta s}{d} = \sqrt{c^2 + 2c}$$

$$b \geq \frac{\Delta s}{c_{gap}}$$

The equivalent stress  $\sigma_v$  shall be evaluated by calculating the tensile stress ( $\sigma$ ) and shear stress ( $\tau$ ) in the loading conditions, when applicable, as specified in [7.1.3](#), [7.1.4](#) and [7.1.5](#) according to the Raghava equivalent stress hypothesis<sup>[1]</sup> and <sup>[2]</sup>:

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + R \cdot \tau^2)}}{2 \cdot R}$$

In this approximated and simplified structural model, only uniaxial tensile or compressive ( $\sigma$ ) and shear ( $\tau$ ) stress components shall be used.

The glazing and bondline parameters shall be:

- $W$  (m), glazing width;
- $H$  (m), glazing height;
- $m$  (kg), glazing mass;
- $m_1$  (kg), glazing mass + 150 (for LC4);

- $d$  (mm), bonding thickness;
- $w$  (mm), bonding width;
- $C_{\text{gap}}$  (mm), sealing gap;
- $p$  (mm), Bonding perimeter, taken at half of bonding width;
- $A = p \cdot w$  (mm<sup>2</sup>), Bonding surface;
- $\Delta s$  (mm), elongation of glass to adjacent structure;
- $c$  (%)– Maximum allowable adhesive elongation.

The comparison between allowable stress and service stress shall be performed in the load cases given in 7.1.2 to 7.1.5. See Annex A for worked examples.

### 7.1.2 LC1 — Static permanent load only applicable to unsupported system

For unsupported glazing systems, the dead load of the glazing is taken by the adhesive joint, reduction factors shall be temperature, static permanent and aging.

$$\sigma_A = \frac{\sigma_{\text{lab}} \cdot f_{\text{redT}} \cdot f_{\text{redS}} \cdot f_{\text{redA}}}{S}$$

Service stress is only the shear component due to glazing self weight:

$$\tau = \frac{m \cdot g}{A}$$

In case of shear, the equivalent stress is:

$$\sigma_v = \tau$$

### 7.1.3 LC2 — Dynamic load

In this load case for tensile stress component, the maximum acceleration due to sea swell,  $a_{\text{max}}$ , of the glazing and the maximum wind pressure or the design load (sea design pressure) are considered, in case of Type 2 bonding arrangements. For shear component, the vertical acceleration,  $a_{\text{max}}$ , due to sea swell and (if the glazing is unsupported) the dead load are considered. Reduction factors shall be temperature, dynamic and aging.

$$\sigma_A = \frac{\sigma_{\text{lab}} \cdot f_{\text{redT}} \cdot f_{\text{redD}} \cdot f_{\text{redA}}}{S}$$

$$\tau_{\text{Unsupp}} = \frac{m \cdot g + m \cdot a_{\text{max}}}{A}$$

$$\tau_{\text{Supp}} = \frac{m \cdot a_{\text{max}}}{A}$$

$$\sigma = \frac{m \cdot a_{\text{max}} + P_{\text{max}} \cdot (H \cdot W)}{A}$$

$$\sigma = \frac{m \cdot a_{\text{max}} + P_D \cdot (H \cdot W)}{A} \quad (\text{Type 2 bonding arrangement})$$

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + 3 \cdot \tau^2)}}{2 \cdot R}$$

#### 7.1.4 LC3 — Fatigue load

In this load case for tensile stress component, the medium acceleration due to sea swell,  $a_{med}$ , of the glazing and the medium wind pressure or the design load (sea design pressure) are considered, in case of Type 2 bonding arrangement. For shear component, the vertical acceleration,  $a_{med}$ , due to sea swell and (if the glazing is unsupported) the dead load are considered; reduction factors shall be temperature, fatigue and aging.

$$\sigma_A = \frac{\sigma_{lab} \cdot f_{redT} \cdot f_{redF} \cdot f_{redA}}{S}$$

$$\tau_{Unsupp} = \frac{m \cdot g + m \cdot a_{med}}{A}$$

$$\tau_{Supp} = \frac{m \cdot a_{med}}{A}$$

$$\sigma = \frac{m \cdot a_{med} + P_{med} \cdot (H \cdot W)}{A}$$

$$\sigma = \frac{m \cdot a_{med} + P_D \cdot (H \cdot W)}{A} \quad (\text{Type 2 bonding arrangement})$$

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + 3 \cdot \tau^2)}}{2 \cdot R}$$

#### 7.1.5 LC4 — Dynamic load (accounting for accidental internal loads)

This follows the same approach as for LC2. The mass of the window + 150 kg,  $m_1$ , is used to account for the additional load due to accidental internal loads. This approach shall only be considered necessary when the conditions of LC4 are met (see 7.2).

$$\sigma_A = \frac{\sigma_{lab} \cdot f_{redT} \cdot f_{redD} \cdot f_{redA}}{S}$$

$$\tau_{Unsupp} = \frac{m_1 \cdot g + m_1 \cdot a_{max}}{A}$$

$$\tau_{Supp} = \frac{m_1 \cdot a_{max}}{A}$$

$$\sigma = \frac{m_1 \cdot a_{max} + P_{wind, max} \cdot (H \cdot W)}{A}$$

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + 3 \cdot \tau^2)}}{2 \cdot R}$$

### 7.1.6 Bondline parameters limitations

In order to limit edge stress concentration effects in the adhesive joint, a limitation shall be considered for the width versus thickness ratio of the bondline as follows:

$$1 \leq \frac{w}{d} \leq 3$$

Other limitations are related to minimum values of the bondline parameters:

- $w \geq 10$  mm;
- $d \geq 6$  mm;
- $C_{\text{gap}} \geq 10$  mm.

See also [Annex B](#).

### 7.2 Design loads

The design loads to be considered for the structural integrity evaluation of the adhesive joint according to the method outlined in [7.1](#) shall be as follows with

$$\left| (T_{\text{design}} - T_{\text{app}}) \right| = 70 \text{ K}$$

#### LC1

Mass of the glazing to be taken by the joint,  $m$  (kg)

Gravity acceleration,  $g = 9,81$  m/s<sup>2</sup>

#### LC2

Acceleration value in strong sea swell conditions,  $a_{\text{max}} = 19,62$  m/s<sup>2</sup> (2 g)

High wind pressure,  $P_{\text{wind,max}} = 2,5$  kPa

#### LC3

Acceleration value in medium sea swell conditions,  $a_{\text{med}} = 9,81$  m/s<sup>2</sup> (1 g)

Medium wind pressure,  $P_{\text{wind,med}} = 1,0$  kPa

For unsupported glazing, all above loading condition shall be considered. For supported glazing, the above loading conditions shall be considered except LC1. For Type 1 and Type 2 bonding arrangements (bonding from inside), water pressure loads  $P_D$  are dominating over wind loads  $P_{\text{wind}}$ , and design loads shall be determined according to 5.5 of ISO 11336-1:2012. For Type 1, the retainer shall be designed according to the design load. This means that the integrity evaluation of the adhesive joint for Type 1 is performed only for inertial and wind loads.

For Type 1 and Type 4 bonding arrangements, the mechanical fastener (retainer) shall be calculated (thickness and fixing) considering the relevant design load:  $P_D$  for Type 1 and  $P_W$  for Type 4.

#### LC4

This case (LC4) accounts for additional accidental internal loads (such as persons, shifting furniture or other outfit items). It is applied as an additional 150 kg mass added to the glazing mass using the LC2 calculation method.

This case shall be only be considered where the following 3 conditions are met:

- height of the bottom side of the window from walking plane < 1 200 mm;

- fixing Type 3 bonding arrangement;
- no additional protections preventing accidental impacts in the plane of the window.

Considered mass,  $m_1$  (kg) = self weight of glazing + 150.

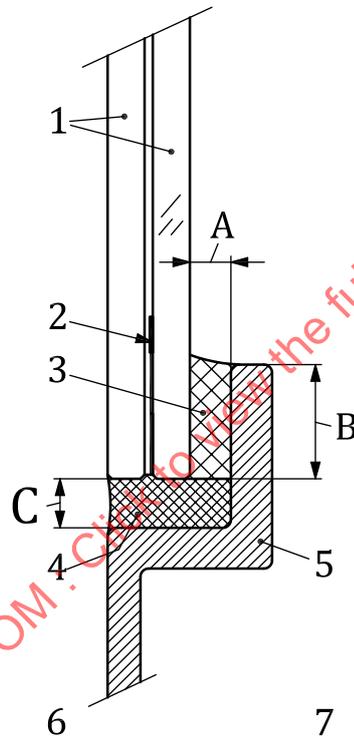
Acceleration value in strong sea swell conditions,  $a_{max} = 19,62 \text{ m/s}^2$  (2 *g*).

High wind pressure,  $P_{wind,max} = 2,5 \text{ kPa}$ .

### 7.3 Design parameters

The structurally bonded joints parameters are shown in [Figures 9](#) and [10](#).

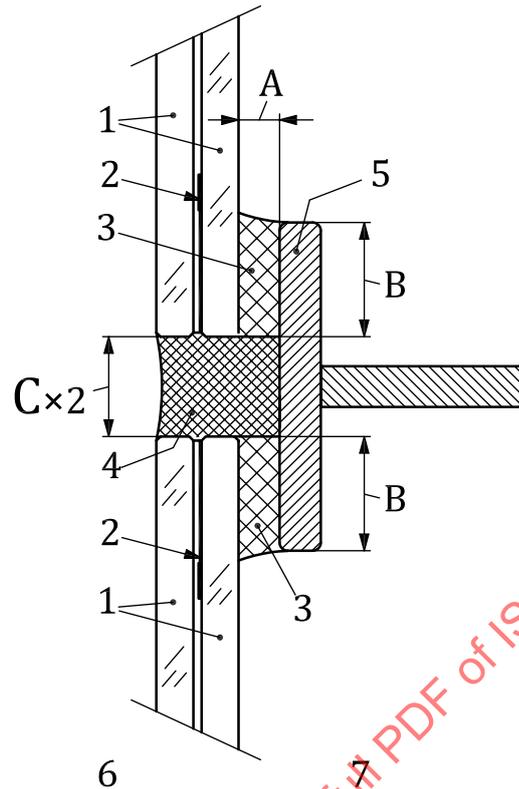
Note that for a glass to glass arrangement ([Figure 10](#), see also [Figure 3](#)), the glass to glass gap shall be 2 × glass to flange gap.



#### Key

- 1 glazing
- 2 UV protection
- 3 bonding material
- 4 sealing material
- 5 substrate
- 6 outside
- 7 inside
- A bonding thickness,  $d$
- B bonding width-  $w$
- C sealing gap,  $C_{gap}$

Figure 9 — Bonded joint parameter “glass to flange”

**Key**

- 1 glazing
- 2 UV protection
- 3 bonding material
- 4 sealing material
- A bonding thickness,  $d$
- B bonding width,  $w$
- C sealing gap,  $C_{\text{gap}}$  (glass to glass)

**Figure 10 — Bonded joint parameters “glass to glass”**

## 8 Bonding installation

### 8.1 Bonding application guidelines

The bonding manufacturers shall provide guidance to the bonding installer to ensure that the product is used as intended. This guidance can include advice on:

- storage and shelf life;
- environmental conditions (during storage, transportation, and installation);
- chemical compatibility;
- surface preparation and priming;
- use of spacer, setting block and resting pad;
- alignment and tolerances;
- mixing and application;

- cure;
- sealing and UV protection;
- maintenance inspection and testing.

## 8.2 Bonding installation procedures

The bonding installer shall develop specific bonding procedures for its products. These shall be used by the workers undertaking the installation, and act as a permanent record that the guidance of the bonding manufacturer was followed.

A typical bonding procedure is included in [Annex C](#).

## 9 Qualification of bonding personnel

Bonding personnel shall be suitably experienced and qualified. ISO 11336-3 details suitable qualification criteria.

## 10 Survey of bonding

Survey requirements for bonding and sealing are detailed in ISO 11336-3.

## 11 Testing

### 11.1 Testing of materials

Adhesive material properties shall be provided by the adhesive manufacturer on the basis of the design parameters outlined in [Clause 7](#), namely:

- $\sigma_{lab}$ , Characteristic strength value at laboratory condition (95 % confidence limit);
- $f_{red,T}$ , Reduction factor for temperature exposure (70 °C);
- $f_{red,S}$ , Reduction factor for permanent static load;
- $f_{red,D}$ , Reduction factor for dynamic cyclic load (10,000 cycles);
- $f_{red,F}$ , Reduction factor for fatigue cyclic load ( $>10^7$  cycles);
- $f_{red,A}$ , Reduction factor for aging conditions;
- $R$ , Ratio compression strength to tensile strength;
- $S$ , Additional material factor as described by the bonding manufacturer, otherwise  $S$  is 1;
- $c$ , Maximum allowable adhesive elongation (or maximum allowable shear strain  $\gamma$ ).

The adhesive material shall be characterised in accordance with DIN 6701-3:2015, Annex A .

The characteristic strength value at laboratory conditions shall be determined using “component-like” specimens, consistent with the actual installation on board, e.g. lap-shear specimen (see EN 1465) or tensile H-specimen (see ISO 8339). The characteristic strength value shall represent the 95 % probability of no failure (see ISO 16269-6).

## 11.2 Proof testing of bonded joint

Where design of the bonded joint does not fulfil the requirements of [Clause 7](#), the bonding design shall be tested. The test apparatus and method shall be consistent with the actual installation on board. For any bond design normally requiring the detailed calculation approach, particular attention shall be paid to the duration of the testing.

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## Annex A (informative)

### Worked example for bondline calculation

#### A.1 Material characteristics

In the worked examples in [A.2](#), the adhesive material properties of [Table A.1](#) are used:

**Table A.1 — Mechanical (minimum) properties of typical adhesive bonding materials**

Characteristic strength, $\sigma_{lab}$ (MPa)	2,5
Reduction factor for temperature, $f_{red,T}$	0,6
Reduction factor for aging, $f_{red,A}$	0,7
Reduction factor for permanent static load, $f_{red,S}$	0,06
Reduction factor for dynamic load, $f_{red,D}$	0,33
Reduction factor for fatigue, $f_{red,F}$	0,11
Ratio compression strength to tensile strength, $R$	1,3
Additional material factor, $S$ (from bonding manufacturer)	1,0
Maximum allowable adhesive elongation, $c$	0,125 (12,5 %)
Maximum allowable strain, $\gamma$	0,515 (51,5 %)
Limit of distance (mm) from glazing edge to the adjacent structure, $C_{gap}$	>10

Linear thermal expansion coefficients of materials are given in [Table A.2](#):

**Table A.2 — Linear thermal expansion coefficients of materials**

Soda-lime float glass	$9 \cdot 10^{-6}$
Aluminum	$24 \cdot 10^{-6}$
Steel	$12 \cdot 10^{-6}$
GRP - Glass Reinforced Plastic	$30 \cdot 10^{-6}$

#### A.2 Worked example

Glazing characteristics:

- glazing width,  $W = 2$  m;
- glazing height,  $H = 1$  m;
- glazing mass,  $m = 100$  kg;
- supporting condition: glazing not supported;
- glazing/seat material: glass/aluminium;
- relative movement,  $\Delta s = 1,174$  mm;

- bondline thickness,  $d = 9,4$  mm (final selected thickness  $d=10$  mm);
- sealing gap,  $C_{\text{gap}} \geq 10$  mm;
- maximum width (evaluated as  $3 \times d$ ),  $w = 28,2$  mm, selected width  $w = 25$  mm;
- mean bonding perimeter,  $p = 5\,900$  mm;
- bonding area,  $A = 147\,500$  mm<sup>2</sup>.

### Structural integrity check:

LC1 – Static load unsupported

$S=1$

$$\sigma_A = \frac{\sigma_{\text{lab}} \cdot f_{\text{redT}} \cdot f_{\text{redS}} \cdot f_{\text{redA}}}{S} = 0,063 \text{ MPa}$$

$$\tau = \frac{m \cdot g}{A} = 0,007 \text{ MPa}$$

$$\sigma_v = \tau = 0,007 \text{ MPa}$$

As  $\sigma_v \leq \sigma_A$ , the result is acceptable.

LC2 – Dynamic load unsupported

$$\sigma_A = \frac{\sigma_{\text{lab}} \cdot f_{\text{redT}} \cdot f_{\text{redD}} \cdot f_{\text{redA}}}{S} = 0,347 \text{ MPa}$$

$$\tau_{\text{Unsupp}} = \frac{m \cdot g + m \cdot a_{\text{max}}}{A} = 0,01995 \text{ MPa}$$

$$\sigma = \frac{m \cdot a_{\text{max}} + P_{\text{max}} \cdot (H \cdot W)}{A} = 0,0464 \text{ MPa}$$

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + 3 \cdot \tau^2)}}{2 \cdot R} = 0,0561 \text{ MPa}$$

As  $\sigma_v \leq \sigma_A$ , the result is acceptable.

LC3 - Fatigue load

$$\sigma_A = \frac{\sigma_{\text{lab}} \cdot f_{\text{redT}} \cdot f_{\text{redF}} \cdot f_{\text{redA}}}{S} = 0,116 \text{ MPa}$$

$$\tau_{\text{Unsupp}} = \frac{m \cdot g + m \cdot a_{\text{med}}}{A} = 0,0131 \text{ MPa}$$

$$\sigma = \frac{m \cdot a_{\text{med}} + P_{\text{med}} \cdot (H \cdot W)}{A} = 0,0199 \text{ MPa}$$

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + 3 \cdot \tau^2)}}{2 \cdot R} = 0,0288 \text{ MPa}$$

As  $\sigma_v \leq \sigma_A$ , the result is acceptable.

LC4 - Dynamic Load unsupported + Accidental Internal Load (see 7.2 for LC4 conditions of application)

$$\sigma_A = \frac{\sigma_{\text{lab}} \cdot f_{\text{redT}} \cdot f_{\text{redD}} \cdot f_{\text{redA}}}{S} = 0,347 \text{ MPa}$$

$$\tau_{\text{Unsupp}} = \frac{m_1 \cdot g + m_1 \cdot a_{\text{max}}}{A} = 0,0491 \text{ MPa}$$

$$\sigma = \frac{m \cdot a_{\text{max}} + P_{\text{max}} \cdot (H \cdot W)}{A} = 0,066 \text{ MPa}$$

$$\sigma_v = \frac{(R-1) \cdot \sigma + \sqrt{(R-1)^2 \cdot \sigma^2 + 4 \cdot R \cdot (\sigma^2 + 3 \cdot \tau^2)}}{2 \cdot R} = 0,102 \text{ MPa}$$

As  $\sigma_v \leq \sigma_A$ , the result is acceptable.

### A.3 Graphs

In the following graphs, the plotted line represents the minimum values of the bonding parameters (bonding thickness and glass to flange gap respectively) versus the long window edge considered for an ideal squared window.

The bonding width,  $w$ , shall be selected within the geometric stability condition:

$$1 \leq w/d \leq 3$$

and it shall be checked in the four load cases (LC1, LC2, LC3 and LC4) as outlined in the above examples.

In the graphs in [Figures A.1](#) and [A.2](#), the areas above the plotted line are permitted, while the areas below the plotted line do not meet the requirements made by this document.

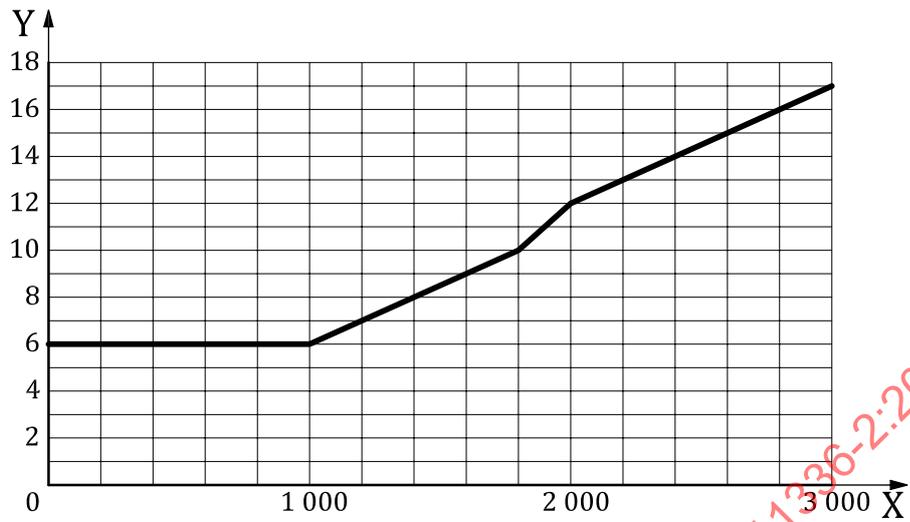
Graphs have been calculated for the following conditions:

$$\Delta T = 70 \text{ K};$$

$$\Delta \alpha = 15 \cdot 10^{-6} \text{ 1/K};$$

$$c = 0,125 \text{ (12,5 \%)};$$

$$C_{\text{gap}} \geq 10 \text{ mm.}$$

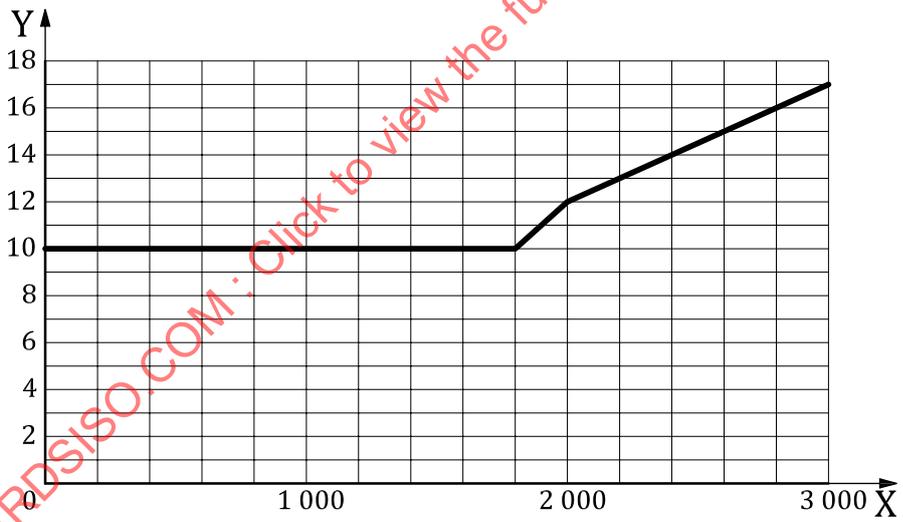


**Key**

Y bonding thickness,  $d$  (mm)

X window long edge (mm)

**Figure A.1 — Bonding thickness,  $d$  (mm)**



**Key**

Y sealing gap,  $C_{gap}$  (mm)

X window long edge (mm)

**Figure A.2 — Sealing gap,  $C_{gap}$  (mm)**