Deutsches Institut für Bautechnik

DIBt

Public-law institution jointly founded by the federal states and the Federation

Technical authority granting approvals and permits for construction products and construction techniques

General construction technique permit

Date: 16 April 2024

Reference number: I 34-1.70.3-54/23

Number:
Z-70.3-278

Validity
from: **16 April 2024**
to: **24 January 2027**

Applicant:
Kuraray Europe GmbH
Philipp-Reis-Straße 4
65795 Hattersheim, Germany

Subject of decision:
Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008

The subject named above is herewith granted a general construction technique permit (*allgemeine Bauartgenehmigung*).
This decision contains five pages and seven annexes.
This general construction technique permit replaces general construction technique permit no. Z-70.3-278 of 24 January 2022.

Translation authorised by DIBt

I GENERAL PROVISIONS

1 The general construction technique permit confirms the fitness for application of the subject concerned within the meaning of the Building Codes of the federal states (*Landesbauordnungen*).

2 This decision does not replace the permits, approvals and certificates required by law for carrying out construction projects.

3 This decision is granted without prejudice to the rights of third parties, in particular private property rights.

4 Notwithstanding further provisions in the 'Special Provisions', copies of this decision shall be made available to the installer of the subject concerned. Furthermore, the installer of the subject concerned shall be made aware of the fact that this decision must be made available at the place of application. Upon request, copies of the decision shall be provided to the authorities involved.

5 This decision shall be reproduced in full only. Partial publication requires the consent of DIBt. Texts and drawings in promotional material shall not contradict this decision. In the event of a discrepancy between the German original and this authorised translation, the German version shall prevail.

6 This decision may be revoked. The provisions contained herein may subsequently be supplemented and amended, in particular if this is required by new technical findings.

7 This decision is based on the information and documents provided by the applicant on the subject concerned during the permit procedure. Alterations to the information on which this general construction technique permit was based are not covered by this decision and shall be notified to DIBt without delay.

II SPECIAL PROVISIONS

1 Subject of the permit and field of application

The subject matter of the permit is the planning, design and execution of glazing using laminated safety glass (VSG) using the Trosifol® Extra Stiff B230 or pro B231 polyvinyl butyral (PVB) film from Kuraray Europe GmbH.

The field of application includes glazing in accordance with the DIN 18008[1] series of standards. The glazing may be executed with or without a static shear interaction of the laminated safety glass panes.

2 Provisions for planning, design and execution

2.1 Planning

The Technical Building Rules, particularly the DIN 18008[1] series of standards as well as the following provisions, shall be observed for planning the glazing.

The laminated safety glass shall consist of at least two flat panes of glass and the Trosifol® Extra Stiff B230 or pro B231 PVB film.

When the glazing is executed using laminated safety glass without a static shear interaction being applied, the composition and manufacture as well as the impact and bond behaviour of the laminated safety glass shall comply with Annexes 1.1 and 1.2. When the glazing is executed using laminated safety glass with a static shear interaction being applied, the adhesion behaviour and the shear moduli shall also comply with Annex 1.1.

It shall be ensured that the glass or interlayer edges are only in contact with adjacent materials that are permanently compatible with the Trosifol® Extra Stiff B230 or pro B231 PVB film. The relevant instructions provided by Kuraray Europe GmbH shall be observed.

2.2 Design

The Technical Building Rules, particularly the DIN 18008[1] series of standards, as well as the following provisions, shall be observed for designing the glazing.

The typical fragmentation pattern for panes of component size required in DIN 18008-1[2], Clause 4.1.3 is guaranteed for the glass panes used in the laminated safety glass; cf. Annex 1.2.

When designing the glazing, the bond effect of the Trosifol® Extra Stiff B230 or pro B231 PVB film may be taken into account for the laminated safety glass if composition and manufacture, impact, adhesion and bond behaviour as well as the shear modulus values of the laminated safety glass are in compliance with Annex 1.

By derogation from the provisions of the DIN 18008[1] series of standards, a linear elastic behaviour of the Trosifol® Extra Stiff B230 or pro B231 PVB film may be assumed for the laminated safety glass under the conditions specified below when verifying the ultimate limit state and serviceability limit state of vertical glazing (facades and interiors) under wind and horizontal line loads or of horizontal glazing (overhead) under snow and wind loads in order to take into account the shear interaction between the individual panes.

For single-pane glazing, the shear modulus values given in Table 1 for the respective load case and a Poisson's ratio of $\mu = 0.49$ may be used as linear elastic characteristics of the Trosifol® Extra Stiff B230 and pro B231 PVB film.

1 DIN 18008 Glass in building – Design and construction rules
2 DIN 18008-1:2020-05 Glass in building – Design and construction rules – Part 1: Terms and general bases

Table 1: Characteristic values applicable to single-pane glazing

Load case		Shear modulus G [N/mm²]	k_{VSG}[3] [-]	k_{mod} [-]
Facades	Load case: wind	7.0	1	0.7
	Load case: horizontal line loads[4]	1.2 (T=30°C) 0.5 (T=35°C) 0.2 (T≤43°C) 0.0 (T>43°C)	1	0.7
	Load case: wind and horizontal line loads	7.0	1	0.7
Indoor	Load case: wind	7.0	1	0.7
	Load case: horizontal line loads	1.2[5]	1	0.7
	Load case: wind and horizontal line loads	7.0	1	0.7
	Load case: self-weight	0.0	1.1	0.25
Overhead use	**Heated areas[6]**			
	Load case: snow	0.58	1	0.4
	Load case: wind and snow	0.58	1	0.7
	Unheated areas[7]			
	Load case: snow	100.0	1	0.4
	Load case: wind and snow	100.0	1	0.7

The values given in Table 1 were determined using a viscoelastic model for the Trosifol® Extra Stiff B230 and pro B231 PVB film. They were simplified for the interlayer by limit cases and correlation analyses for the actions for practical application with a calculation method under a linear-elastic approach. If boundary conditions and actions other than those specified in Table 1 are to be verified, the respective shear modulus may be verified in accordance with the procedure in Annex 7. Usually, a project-related construction technique permit is additionally required for this.

The calculations may be geometrically linear or non-linear. The following sequence shall be observed for verification purposes:

1) Load case combinations in accordance with DIN EN 1990[8] including the associated partial safety factors and combination coefficients shall be formed.
2) The main tensile stresses in the laminated safety glass shall be calculated separately for each load component (γ-,·ψ-fold load) of the relevant load case combination. The following system assumptions shall be observed:
   - For wind, horizontal line and snow loads, a partial shear interaction in accordance with Table 1 may be used for the calculation.

3 k_{VSG} Factor for laminated glass and laminated safety glass, see DIN 18008-1, Section 8.3.9

4 T Interlayer temperature
Intermediate values of the listed shear moduli may be linearly interpolated. Interlayer temperatures T > 43°C are not covered.

5 Valid for a permissible interlayer temperature T of 30°C and a load time of one hour; for higher interlayer temperatures T, shear modulus values for outdoor applications shall be taken into account.

6 Valid for a load period of 30 days and at a temperature of 23°C

7 Valid for a load period of 30 days and at a temperature of 0°C

8 DIN EN 1990 Eurocode: Basis of structural design

- For climate loads (temperature, atmospheric pressure, difference in altitude), the method specified in Clause 7.2 of DIN 18008-1[2] shall be used. The extreme cases 'without shear interaction' and 'full shear interaction' shall be considered. The more unfavourable case shall be taken.
- No shear interaction shall be considered for the calculation of the other load cases (e.g. self-weight).

3) The main tensile stresses shall then be added up for each load component for the load case combination considered.

4) The load-bearing capacity shall be verified in accordance with DIN 18008-1[2] for the relevant load case combination in consideration of the k_{mod} and k_{VSG} coefficients in accordance with Table 1.

2.3 Execution

The Technical Building Rules, particularly the DIN 18008[1] series of standards, shall be observed for executing the glazing.

The executing company shall provide a declaration of conformity in accordance with Section 16a(5) in conjunction with Section 21(2) of the Model Building Code to confirm the conformity of the construction technique with this general construction technique permit.

3 Provisions for use, maintenance and repair

Damaged panes shall be replaced immediately. Hazardous areas shall be sealed off immediately. When replacing the panes, it shall be ensured that solely construction products to which this general construction technique permit applies are used.

Andreas Schult
Head of Section

Drawn up by
Stöhr

A 1.1 Composition and manufacture of the laminated safety glass

- The glass panes consist of the following glass products:
  - float glass (soda lime silicate glass) in accordance with DIN EN 572-2[1],
  - safety glass in accordance with DIN EN 12150-1[2] with a fragmentation pattern in accordance with Annex 1.2, A 1.3,
  - heat-soaked thermally toughened soda lime silicate safety glass in accordance with DIN EN 14179-1[3] or DIN 18008-2[4], Clause 4.3, 3rd bullet point, with a fragmentation pattern in accordance with Annex 1.2, A 1.3,
  - heat strengthened glass in accordance with DIN EN 1863-1[5] with a fragmentation pattern in accordance with Annex 1.2, A 1.3,
  - coated glass in accordance with DIN EN 1096-1[6] - with coatings with properties at least equivalent to black enamelled glass in terms of absorption performance and the resultant interlayer temperature,
  - patterned glass in accordance with DIN EN 572-5[7] - with compliance with the limit values for straightness (local and global warping) of the side facing the interlayer for thermally non-toughened patterned glass for heat strengthened glass in accordance with DIN EN 1863-1[5] and safety glass in accordance with DIN EN 12150-1[2].
- The nominal thicknesses of the PVB film Trosifol® Extra Stiff B230 and pro B231 are 0.76 mm, 1.52 mm, 2.28 mm or 3.04 mm. The technical data are deposited with DIBt (last update 16 April 2024).
- The PVB films have the following properties as determined in accordance with DIN EN ISO 527-3[8] (test speed: 50 mm/min, test temperature: 23°C):
  Trosifol® Extra Stiff B230: Tensile strength: 34 N/mm²; elongation at break: 202%.
  Trosifol® Extra Stiff pro B231: Tensile strength (longitudinal/transverse): 40.19 N/mm²/35.66 N/mm²
  Elongation at break (longitudinal/transverse): 200%/184%.
- The moisture content of the film during manufacture is ≤ 0.55%, measured in accordance with **Annex 7**.
- When manufacturing laminated safety glass using coated glass products (excluding enamelled glass products), the glass panes are laminated with the PVB film Trosifol® Extra Stiff B230 or pro B231 only on the uncoated glass surface.
- The dimensional tolerances in accordance with Section 4.1.2.1 of DIN EN ISO 12543-5[9] apply.
- The laminated safety glass is manufactured using the laminating process described in the TROSIFOL® Manual, last update 2014.

A 1.2 Performance values

- Impact behaviour tested in accordance with DIN EN 12600[10] (4 mm float/0.76 mm PVB/4 mm float): Trosifol® Extra Stiff B230: 1(B)1; Trosifol® Extra Stiff pro B231: 2(B)2.
- Impact behaviour tested in accordance with DIN EN 356[11] (4 mm float glass/0.76 mm PVB/4 mm float): P1A.
- Impact behaviour of laminated safety glass with Trosifol® Extra Stiff B230 tested in a ball drop test in accordance with DIN 52338[12]: no penetration of the ball from a drop height of ≥ 4m
- Laminate bond strength (pummel test) tested in accordance with **Annex 3**: Pummel value ≥ 4
- Adhesion tested in accordance with **Annex 4**: mean value shear strength $\sigma \geq 15$ N/mm²
- Shear modulus values tested in accordance with **Annexes 5.1 to 5.3**: see **Annex 6**

[1]	DIN EN 572-2:2012-11	Glass in building – Basic soda lime silicate glass products – Part 2 – Float glass
[2]	DIN EN 12150-1:2019-08	Glass in building – Thermally toughened soda lime silicate safety glass – Part 1: Definition and description
[3]	DIN EN 14179-1:2016-12	Glass in building – Heat soaked thermally toughened soda lime silicate safety glass – Part 1: Definition and description
[4]	DIN 18008-2:2020-05	Glass in building – Design and construction rules – Part 2: Linearly supported glazings
[5]	DIN EN 1863-1:2012-02	Glass in building – Heat strengthened soda lime silicate glass – Part 1: Definition and description
[6]	DIN EN 1096-1:2012-04	Glass in building – Coated glass – Part 1: Definitions and classification
[7]	DIN EN 572-5:2012-11	Glass in building – Basic soda lime silicate glass products – Part 5: Patterned glass
[8]	DIN EN ISO 527-3:2003-07	Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets
[9]	DIN EN ISO 12543-5:2011-12	Glass in building – Laminated glass and laminated safety glass – Part 5: Dimensions and edge finishing
[10]	DIN EN 12600:2003-04	Glass in building – Pendulum tests – Impact test method and classification for flat glass
[11]	DIN EN 356:2000-02	Glass in building – Security glazing – Testing and classification of resistance against manual attack
[12]	DIN 52338:2016-10	Test methods for flat glass in building – Ball drop test for laminated glass

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 1.1
Composition and manufacture, performance values	

A 1.3 Fragmentation pattern

Glass products in accordance with EN 12150-2[13] and EN 14179-2[14] must have the fragmentation pattern defined in DIN EN 12150-1[2] for test panes for each manufactured component size.
Glass products in accordance with EN 1863-2[15] with a component size of 1000 mm x 1500 mm and more must have a fragmentation pattern in which the proportion of the area made up of fragments of a non-critical size is more than four-fifths of the total area. The method for assessing the fragmentation pattern is based on DIN EN 1863-1[4], Section 8. All fragments in which a circle of diameter 120 mm can be drawn may be deemed non-critical in terms of size.

[13] In Germany implemented by DIN EN 12150-2:2005-01.
[14] In Germany implemented by DIN EN 14179-2:2005-08.
[15] In Germany implemented by DIN EN 1863-2:2005-01.

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 1.2
Composition and manufacture, performance values (continuation)	

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A 2 Instructions for testing the laminate bond strength (pummel test)

A 2.1 General

- The test specimens are manufactured in accordance with the TROSIFOL® Manual, last update 2014.
- The standard dimensions of the test specimens are 80 mm x 150 mm.
- Standard composition: 3 mm float / 0.76 mm Trosifol® Extra Stiff / 3 mm float.
- Number of test specimens: at least 5

A 2.2 Conducting the test

- The test specimens are conditioned for at least 4h at +5°C (± 2°C).
- The test specimen is held at an angle of approx. 5° to the plane of the pummel plate or placed on the striking tool so that only the edge of the unbroken glass is in contact with the plate (Fig. A 2.1).
- The test specimen is repeatedly struck with a hammer (500 g flat-head hammer) in an overlapping pattern (uniform strikes, starting at the bottom edge, overlapping half of the previous strike area, spacing approx. 20 mm) to break the glass into powdered particles. At least 6 to 10 cm of the laminate is struck (Fig. A 2.1).
- Then turn the laminate over (short end over short end) and repeat the process. Both ends (the inside of one end and the outside of the other) are struck and read. On completion, the centre section, which contains the specimen ID, should be the only glass that has not been crushed.

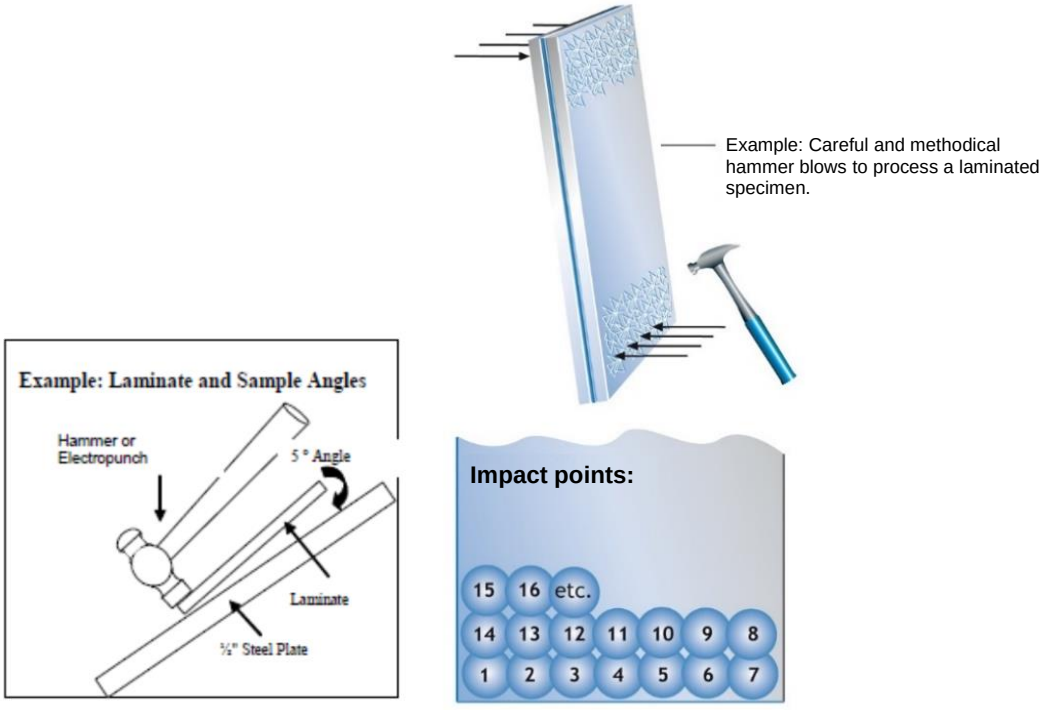

Fig. A 2.1: Conducting the test

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 2.1
Instructions for testing the laminate bond strength (pummel test)	

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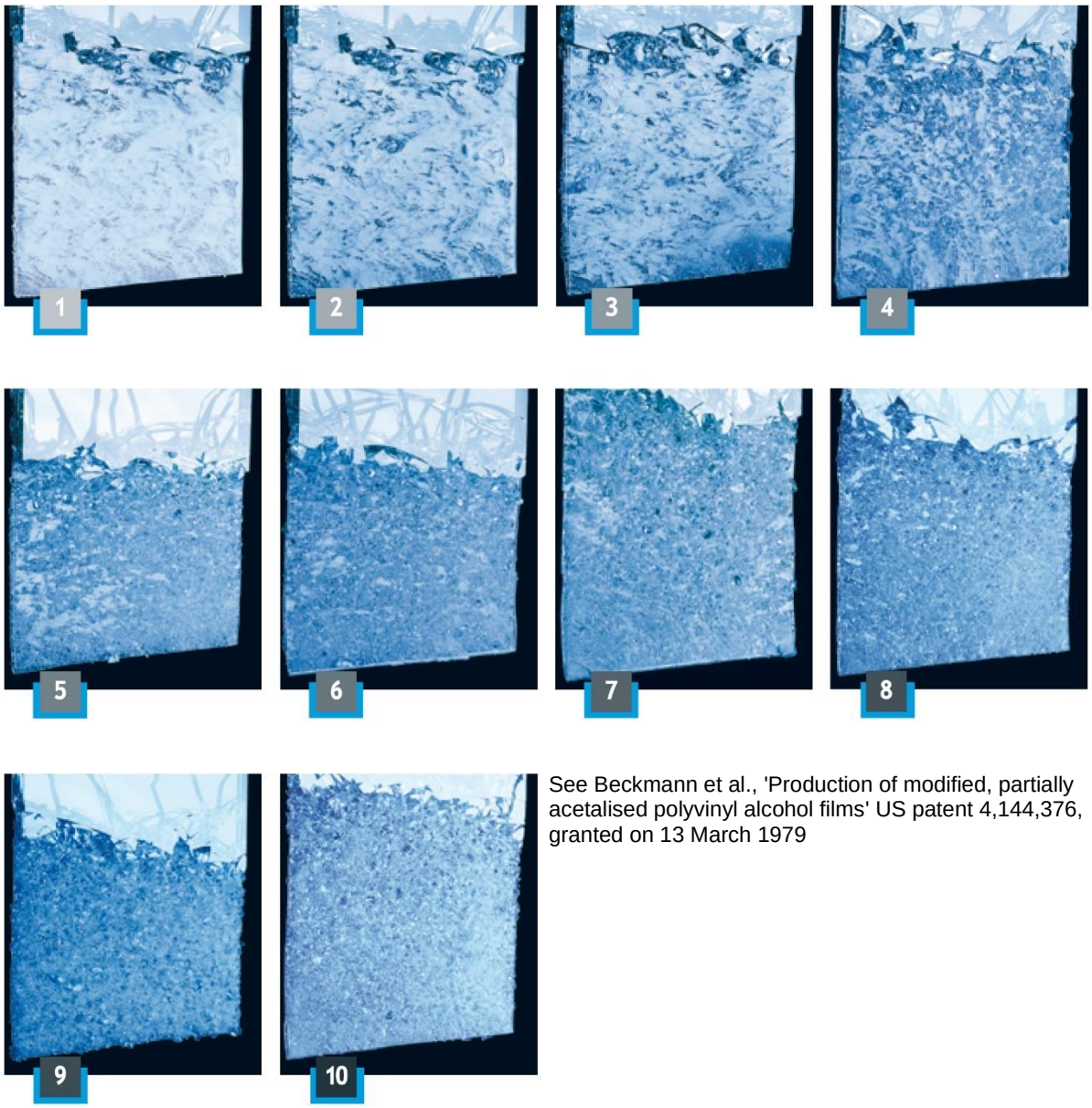
A 2.3 Evaluation

- The specimens are placed on brown kraft paper, carefully compared with the reference specimens and the degree of bonding (0 to 10) is determined by comparing the specimens with the reference specimens (Fig. A 2.2).
- A pummel value of 0 means no bonding, a pummel value of 10 means very high bonding.



See Beckmann et al., 'Production of modified, partially acetalised polyvinyl alcohol films' US patent 4,144,376, granted on 13 March 1979

Fig. A 2.2: Reference pummel pattern

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 2.2
Instructions for testing the laminate bond strength (pummel test)	

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A 3 Instructions for compression shear test

A 3.1 General

- The laminated safety glass is manufactured in compliance with the TROSIFOL® Manual, last update 2014.
- Standard composition of the test specimen: 3 mm float / 0.76 mm Trosifol® Extra Stiff / 3 mm float.
- At least 10 square (plane-parallel with smooth edges) test specimens with an edge length of 25 mm are cut out of a laminated safety glass using a suitable glass cutter.
- The test specimens taken are stored for at least 4 hours under normal climatic conditions (23°C/50% RH). A storage period of more than 24 hours is not permissible, as there is a risk of the test specimens absorbing moisture at their edges.
- A tensile testing machine, into which the specimen holder is inserted, is used as the testing device (Fig. A 3). The holder consists of two jaws, the surfaces of which are angled at 45° to one another. The specimen is placed in the recess of the lower jaws, which are mounted on a horizontally movable carriage. The upper jaw is firmly clamped into the movable part of the testing machine.
- Number of test specimens: at least 10 to determine the performance values; at least 5 for FPC.

A 3.2 Conducting the test

- Before a specimen is inserted, the two jaws are moved together as far as they will go and adjusted so that the edges are parallel to one another.
- After the specimen has been inserted, the two jaws are pushed together at a feed rate of 2.5 mm/min until one glass side has sheared off from the film.
- The maximum force F_s required to separate the laminated safety glass is read from the testing machine's display.

A 3.3 Evaluation

- The mean values of the shear strengths σ are determined from the shear forces F_s determined in the test, taking into account the geometry of the test specimens.

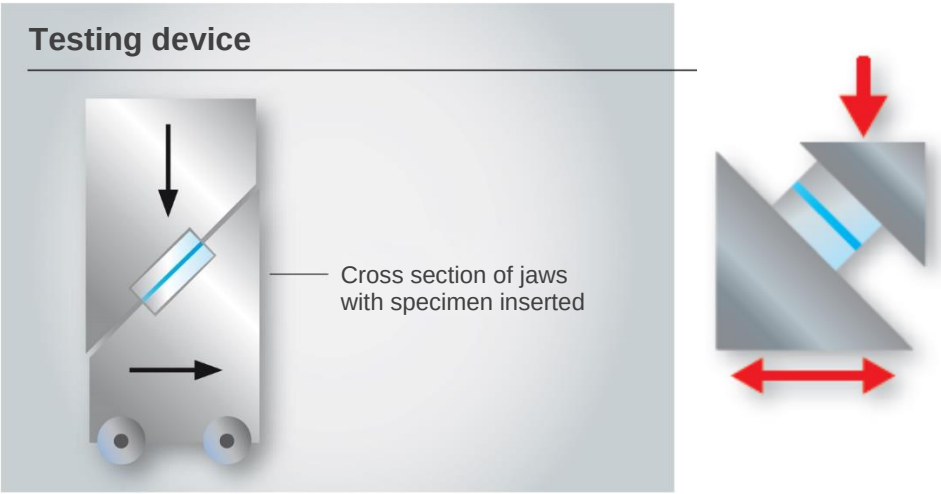

Fig. A 3: Testing device

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 3
Instructions for compression shear test	

A 4 Test instructions for determining the shear moduli G(t,T)

A.4.1 General

Dynamic mechanical thermal analyses (DMTA) are conducted to experimentally characterise the temperature- and load duration-dependent material behaviour of polymeric interlayers. In a DMTA, the viscoelastic body is excited at a controlled temperature by means of harmonically oscillating distortion or stress and the phase-shifted stress or distortion response is measured. The time- and temperature-dependent stiffness characteristics G(t;T) can be determined by varying the excitation frequency and temperature. The measurements are taken in the rheometer.
Torsional relaxation tests are conducted on the glass-film laminate to validate the DMTA.
The procedure is described in general in DIN EN 16613[1] and the ISO 6721[2] series of standards.

A 4.2 DMTA test description

A 4.2.1 Conducting the test

Table T 4.1 shows the description of the test in the rheometer. The rheometer is shown in Fig. A 4.1.
Tab. T 4.1: Test description

Testing machine	Rheometer	
Preparing the specimen	Punched out using a hole punch	
Specimen storage	At least 2 days dry (e.g. Steiner Chemie drying beads), room temperature	
Measuring system	Plate-plate system	
Specimen geometry	Circle: Ø 8 mm, d=0.76 mm	
Normal contact force	0.1 [N] (pressure)	
Number of specimens	3	
	Amplitude measurement	**Temperature/frequence measurement**
Temperature	+100°C; +40°C; -20°C	[100°C to -20°C], cooling in 5°C steps, nitrogen
Frequencies	0.1Hz; 1Hz; 10Hz	[0.1Hz to 10Hz]
Distortion amplitude	[0.01% to 0.25%] at -20°C otherwise [0.01 to 0.1]%	0.1 % at T [100°C to +40°C]; 0.025 % at T [40°C to -20°C]

A 4.2.2 Rheometer test results

A 4.2.2.1 Amplitude measurement

- Storage modulus G' as a function of the applied distortion/stress amplitude
- Loss modulus G'' as a function of the applied distortion/stress amplitude
- Complex modulus G* as a function of the applied distortion/stress amplitude

1 DIN EN 16613:2020-01 Glass in building – Laminated glass and laminated safety glass – Determination of interlayer viscoelastic properties
2 ISO 6721 Plastics - Determination of dynamic mechanical properties

A 4.2.2.2 Temperature/frequency measurement

- Storage modulus G' as a function of frequency and temperature
- Loss modulus G'' as a function of frequency and temperature
- Complex modulus IG*I as a function of frequency and temperature
- Loss factor tan δ= G''/G' as a function of frequency and temperature

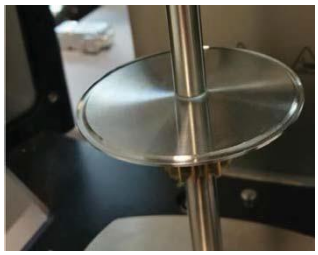

Fig. A 4.1: Test set-up, rheometer

A 4.2.3 Analysis and evaluation

As long as the storage modulus, loss modulus and complex modulus from the amplitude measurement are independent of the applied distortion amplitude or stress amplitude, the material is in the linear viscoelastic range.
The master curve is generated at a reference temperature of T_{ref} = 20°C by the gradual displacement of the measured isothermal IG*I modulus/frequency curves horizontally along the frequency axis. The horizontal displacement factors may be approximated mathematically by the time/temperature displacement principle of William-Landel-Ferry or Arrhenius. If these do not adequately represent the displacement factors over the entire temperature range under examination, the incrementally determined displacement factors are used.
The Prony series is determined by taking into account the master curves of the storage modulus G' and the loss modulus G''.

$$G(t) = G_0 \cdot \left(1 - \sum_{i=1}^{n} g_i \left(1 - e^{-\frac{t}{\alpha_T(T,T_{ref})\cdot\tau_i}}\right)\right)$$

This series is then used to obtain the shear modulus values G(t,T), see **Annex 5**, Fig. A 5.1.

A 4.3 Test instructions for torsional relaxation tests

A 4.3.1 General

- The laminated safety glass is manufactured in compliance with the TROSIFOL® Manual, last update 2014.
- Composition: 6 mm heat strengthened glass/0.76 mm Trosifol® Extra Stiff/ 6 mm heat strengthened glass
- Dimensions: 1100 ± 5 mm x 360 ± 5 mm (L x W)
- Number: at least 3 test specimens per temperature.
- The test setup consists of a measuring channel for the deflection in the centre of the span and/or for the drilling angle and the torsional moment and the temperature of each glass laminate. The temperature is measured on the outside of the glass laminate.
- The test set-up is shown in Fig. A 4.2.

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 4.2
Test instructions DMTA and torsional relaxation tests	

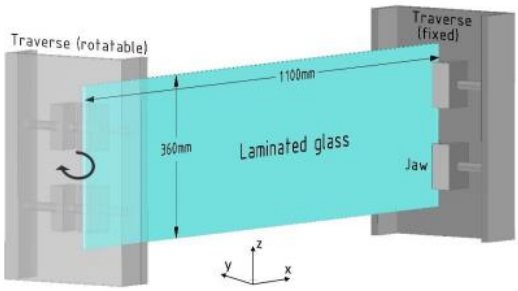

Fig. A 4.2: Torsional relaxation test

A 4.3.2 Conducting the test

- Specimens conditioned for 24 hours at room temperature.
- Angle of twist of 2° applied in a short time, but quasi-statically.
- Measurement at 0°C, 23°C and 50°C
- Load duration at least 24 h.
- Angle of twist, torsional moment and the temperature of each test specimen are recorded (starting together with conditioning).

A 4.3.3 Evaluation

- The shear moduli are determined for different points in time and temperatures, see **Annex 5**, Fig. A 5.2.
- The shear moduli are determined as mean values from the tests.

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 4.3
Test instructions DMTA and torsional relaxation tests	

A 5 Shear modulus values G(T,t), determined by testing

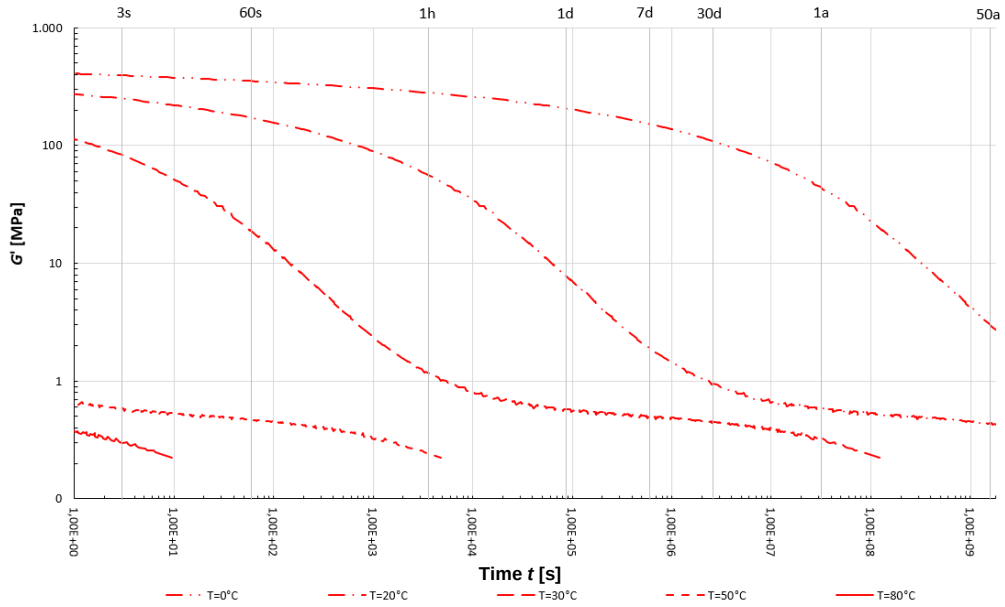

Fig. A 5.1 Shear modulus G(T,t) from DMTA as a function of temperature T and load duration t

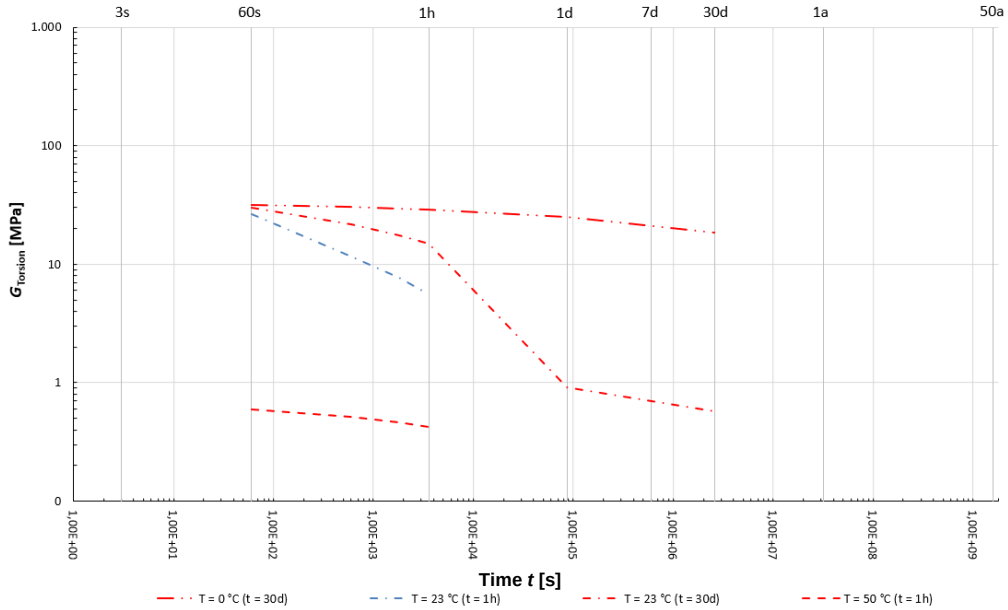

Fig. A 5.2 Shear modulus G(T,t) from torsional relaxation tests as a function of temperature T and load duration t

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 5
Shear modulus G(t,T)	

Deutsches Institut für Bautechnik DIBt

A 6 Principle of moisture measurement using NIR spectroscopy

A 6.1 General principle

To determine the moisture content of the laminated film in a laminated glass specimen, a spectral scan is performed in the near infrared range of the spectrum from 1450 to 2200 nm. The absorption caused by moisture in the specimen is in the range 1875-1950 nm and is corrected for the specimen thickness by dividing it by the absorption caused by CH2 groups at 1730 nm.

Correlating Karl Fischer moisture analyses ('MOISTURE Standards') with this NIR ratio allows the percentage moisture content to be calculated. To calibrate and adjust the NIR spectrometer, laminated safety glass specimens with a precisely defined moisture content are prepared and provided in advance. The moisture content of these specimens ('MOISTURE STANDARDS') is determined by Karl Fischer titration (KFT).

The constants are to be determined for the glass substrates used (type of float glass and thickness) and used accordingly (note: laboratories typically work with identical base glass of the same thickness in all cases. Knowledge and experience of conducting and evaluating NIR spectroscopy are required.

A 6.2 Conducting the test

- The NIR spectrophotometer is set up to scan the range from 1450 to 2200 nm.
- The laminated safety glass specimen is cleaned, placed in the spectrophotometer and scanned in the NIR range. A typical scan is shown in Fig. A 6.
- The CH2 absorption is measured from the horizontal tangent to the 1730 nm peak and from a second horizontal baseline to the minimum close to 1575 nm (the minima are to be defined and specified in the wavelength range).
- The moisture absorption is measured from the maximum in the range of 1875–1950 nm to the tangent between the two minima at nominally 1873 and 2087 nm.

A 6.3 Evaluation

- The NIR ratio is the moisture absorption divided by the CH2 absorption.
- The percentage humidity is calculated using the following equation.

$$\%H_2O = \mathbf{A} * (\text{NIR ratio}) - \mathbf{B}$$

- A and B are constants that vary depending on the spectrophotometer, glass colour and glass thickness.

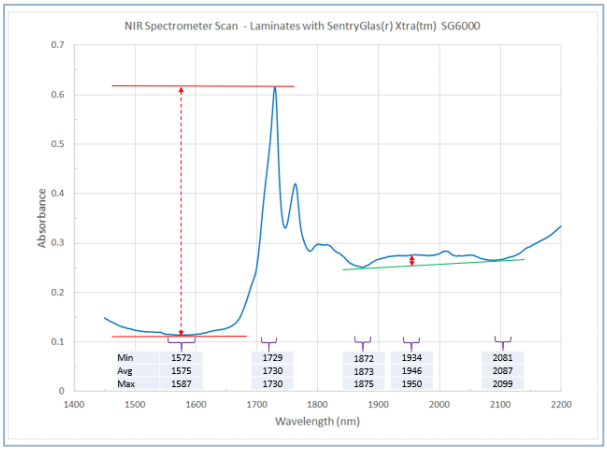

Fig. A 6: Typical scan

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 6
Principle of moisture measurement using NIR spectroscopy	

A 7 Displacement function and Prony series

For actions that deviate from Table 1 and for calculation methods that can take into account the viscoelastic properties of the interlayer, the displacement function of equation (G 7.1) and the values of the Prony parameters given in Table T 7.1 may be used in equation (G 7.2). The respective temperature and equation (G 7.2) are first used to calculate the displacement factor a_T, which is then multiplied by the relaxation time τ_i in equation (G 7.1).

Temperature range 0°C to +70°C.

$$G(T,t) = G_0 \cdot \left(1 - \sum_{i=1}^{n} g_i \left(1 - e^{-\frac{t}{\alpha_T \cdot \tau_i}}\right)\right) \quad \text{(G 7.1)}$$

$$\log_{10} a_T(T) = 5.1496 \cdot 10^{-5} \cdot T^3 - 4.6503 \cdot 10^{-3} \cdot T^2 - 1.0685 \cdot 10^{-1} \cdot T + 3.585152 \quad \text{(G 7.2)}$$

where:

$\log_{10} a_T(T)$: Displacement function for calculating the master curve at a reference temperature of 20°C
T: Film temperature to be examined in each case in [°C]
$G(t)$: Shear modulus as a function of time t in [Nmm^{-2}]
G_0: Initial shear modulus (456 Nmm^{-2})
g_i: Dimensionless shear modulus [-] see Table T 7.1
τ_i: Relaxation time [s] see Table T 7.1
t: Load period to be examined in each case

Table T 7.1: Prony parameters for a reference temperature of $T_{ref} = 20$°C

Relaxation time τ_i [s]	Dimensionless shear modulus g_i [-]
1.0E+08	1.33727900E-03
1.0E+07	4.04015787E-04
1.0E+06	2.40827400E-03
1.0E+05	1.75355355E-02
1.0E+04	1.01707925E-01
1.0E+03	1.97590634E-01
1.0E+02	1.95890854E-01
1.0E+01	1.73716847E-01
1.0E+00	1.17163446E-01
1.0E-01	1.92245189E-01

Glazing made of laminated safety glass using the Trosifol® Extra Stiff B230 or pro B231 PVB film with shear interaction for application in accordance with DIN 18008	Annex 7
Displacement function and Prony series	