Stiffness family – Saflex® Structural interlayers

Introduction
Saflex® DG structural PVB interlayer is a tough, resilient film produced from plasticized polyvinyl butyral resin (PVB). It is designed specifically for applications where increased interlayer rigidity and high glass adhesion are required relative to conventional glazing interlayers. The designed high adhesion may render this product inappropriate for lamination with thin annealed lites of glass when used as a single layer interlayer if penetration resistance is required.

Saflex DG structural PVB combines a stiffer interlayer, versus conventional PVB interlayers, with features such as glass containment upon breaking, UV screening, low haze and the ability to laminate thick multi-ply glass. Storage, assembly and lamination properties similar to other Saflex brand PVB interlayer products, along with the aforementioned properties, make Saflex DG structural interlayer an excellent choice for most structural applications. Information regarding the safe handling and storage of Saflex DG PVB can be found in the Safety Data Sheet that is available from Eastman or at www.saflex.com. Lamination procedures are documented in the Saflex Lamination Guide which is available by contacting your Eastman Technical Service representative.

Specific applications of Saflex DG structural PVB interlayer include its use in structural glass applications such as: balconies, floors, fins and stair treads. It may also be used in glass applications where creep at higher temperatures is a concern and in areas where the edge effects from sealants or exposed laminate edges need to be minimized. When used as part of a multi-interlayer laminate glazing system in place of one layer of standard PVB, Saflex DG structural interlayer can provide increased infill retention due to lower deflection as compared to a similar laminate system without Saflex DG interlayer. Saflex DG structural interlayer can be layered with Vanceva and Saflex colors. The modulus of the interlayer should be adjusted accordingly for calculations and color mottle should be verified through mock up panels.

The generic physical and mechanical properties of Saflex DG structural PVB interlayer are provided in the Product Technical Datasheet. The information in this document is directed to provide guidance for a stiffness family determination for product family of Saflex DG as outlined in prEN16613:2017 (E) as published in April 2017.

Normative context
The scope of prEN16613:2017 (E) is defined as follows: This European Standard specifies a test method for determining the mechanical viscoelastic properties of interlayer materials. The interlayers under examination are those used in the production of laminated glass and/or laminated safety glass. The interlayer properties are needed in order to determine the load resistance of laminated glass in accordance with prEN 16612:2017.

From the tensile modulus in particular conditions of temperature and load duration, an interlayer can be placed into a family that relates to a specific interlayer shear transfer coefficient, ω. This value can be used in the simplified calculation method described in prEN 16612:2017.

A number of significant changes has taken place since the publication of prEN 16613(2013) and prEN 16612 (2013). It should be noted that there are ongoing developments around these draft standards. Whereas Eastman believes this document is accurate at the time of writing (see date on document), the reader should verify no relevant changes have been taken since.

It is important to understand modifications that have taken place since 2013:

1) The scope of prEN16612 has been proposed to be limited to be lateral loads on infill panels that are uniformly supported. The scope is still under discussion and prEN 16612 has not been sent for enquiry yet. Since prEN16613 is closely tied to prEN16612 for e.g. stiffness family determination as evident by the scope of the former, this is somewhat unsatisfactory. Many glass applications where interlayer properties are most important for structural performance (single side clamped glass, point-fixed glazing) are excluded from the proposed scope of prEN16612. The simplified method for effective thickness calculation has been moved to an informative annex in the proposed version of prEN16612

2) The number of stiffness families has been reduced from 4 to 3, as follows:

Interlayer type	prEN16613(2013) stiffness family	prEN16613(2017)(E) stiffness family
"Non-described"	0	0
"Acoustic"	1	0
"Standard PVB"	2	1
"Structural"	3	2

3) Climate load scenarios and wind storm load scenarios have been added to both prEN16613 and prEN16612. The Mediterranean wind gust load scenario has been altered (Temperature from 30 °C to 35 °C), along with a change of the modulus criterion. The modulus criterion for personal crowds has been changed. Default shear transfer coefficients for Mediterranean wind loads (gust and storm), other storm loads and climate loads are lacking still in the proposed prEN16612.

An overview of the load scenarios from prEN16613 and/or prEN16612 is given in Annex 1.

Interlayer modulus data

The interlayer shear storage and Young's modulus are important parameters for engineers to calculate the stresses and deflections that occur as a result of specific loads on laminated glass building elements. The values of these properties for viscoelastic interlayers, such as Saflex DG interlayer, are a strong function of temperature and load duration and are included in the Product technical sheet. For the purposes of stiffness family determination, an independent characterization was carried out at the State Materials Testing Institute (Materialprüfungsanstalt, or MPA), Institute for Materials Technology, Darmstadt, Germany. The methodology follows the generic procedure of prEN16613, and where deviations occur they are in line with the recommendations of ISO 6721. Experimental details and modulus values are included in the institute's report (Annex 2).

Stiffness family determination

Based on interlayer modulus values as listed in the report, an interlayer stiffness family was executed for the load scenarios as proposed in prEN16613 (2017)E. To convert the measured shear storage modulus, G_L to Young's modulus E_L, which is used in prEN 16613 as the basis for stiffness family determination, Equation 1 may be used:

$$E_L = 2G_L(1+\mu) \quad (1)$$

where μ is the Poisson's ratio value of the interlayer. Section 5.1 in prEN16613 specifies *(μ equals 0.49 for an isotropic interlayer*), that the approximation in eq. 2 is applicable:

$$E_L \approx 3G_L \quad (2)$$

Equation 2 may be used to categorize the structural PVB interlayer under various load scenarios into different stiffness families according to the conditions specified in prEN16613.

The results are listed in Table 1.

Table 1. Stiffness family determination as per prEN16613(2017E) for Saflex DG and Saflex DG XC interlayer, based on independent data (MPA 2017). Young's modulus is represented by *E*.

Load case	E_{min} for family 2 (MPa)	*E* Saflex DG (MPa)	*E* Saflex DG XC (MPa)	Stiffness family	ω
1) Wind gust load (Mediterranean areas)	>20	75	80	2	0.5
2) Wind gust load (other areas)	>100	859	813	2	0.7
3) Wind storm load (Mediterranean areas)	>1	2.8	2.7	2	0.1
4) Wind storm load (other areas)	>20	419	432	2	0.5
5) Personnel balustrade loads – normal duty	>20	110	117	2	0.5
6) Personnel balustrade loads - crowds	>10	22	26	2	0.3
7) Glass for walking on for maintenance	>1	1.8	1.5	2	0.1
8) Snow load -roofs of unheated buildings	>10	13*	19*	2	0.3
9) Snow load - roofs of heated buildings	>1	5.2	6.7	2	0.1
10) Climate load IGU (summer)	>1	1.4	1.3	2	0.1
11) Climate Load IGU (winter)	> 10	71	94	2	0.3

* For snow loads on unheated buildings, the data at 20 °C are used as a worst-case scenario, still meeting the Young's modulus requirement for stiffness family 2 for this load scenario at 0 °C.
Interlayer values based on nominal 0.76 mm interlayer thickness
NA = not available

Saflex DG and Saflex DG XC can be classified as stiffness family 2 materials according to the data as reported in Annex 2.

ANNEX 1

Load scenario's and stiffness family criteria in prEN16613

prEN16613 load scenarios (2017)				
	Load case	Load duration	Max T	Required for family 2
			(°C)	E (MPa)
1)	Wind gust load (Mediterranean areas)	3 s	35	>20
2)	Wind gust load (other areas)	3 s	20	>100
3)	Wind storm load (Mediterranean areas)	10 min	35	>1
4)	Wind storm load (other areas)	10 min	20	>20
5)	Personnel balustrade loads – normal duty	30 s	30	>20
6)	Personnel balustrade loads - crowds	5 min	30	>10
7)	Glass for walking on for maintenance	30 min	40	>1
8)	Snow load - roofs of unheated buildings	3 weeks	0	>10
9)	Snow load - roofs of heated buildings	5 days	20	>1
10)	Climate load IGU (summer)	6 hours	40	>1
11)	Climate Load IGU (winter)	12 hours	20	>10
12)	Permanent	50 years	60	NA

NA = not applicable

ANNEX 2

Test report K 17 1167

Zentrum für Konstruktionswerkstoffe
Staatliche Materialprüfungsanstalt Darmstadt
Fachgebiet und Institut für Werkstoffkunde
Prof. Dr.-Ing. Matthias Oechsner

TECHNISCHE UNIVERSITÄT DARMSTADT

Untersuchungsbericht K 17 1167

Test report

1. Ausfertigung
1st Copy

Auftraggeber: *Customer:*	Eastman Chemical B.V. Fascinatio Boulevard 612 2909 VA Capelle aan den Ijssel The Netherlands
Auftrag vom: *Order dated:*	21.06.2017 — Bestell-Nr. oder Zeichen: *Order-No. or reference:* 43383677
Auftrag über: *Order for:*	**Ermittlung mechanischer Eigenschaften an Kunststoff-Folien** ***Determination of mechanical properties of plastic sheets***
Prüfgut: *Test material:*	2 Folien mit der Bezeichnung: „Saflex DG41 #2“ und „Saflex DG41 XC #2“ *2 sheets with marking: "Saflex DG41 #2" and "Saflex DG41 XC #2"*
Prüfgutentnahme: *Sample dispatch mode*	Das Prüfgut wurde vom Auftraggeber angeliefert *The sample pieces have been delivered by the customer*
Prüfguteingang: *Delivery of samples:*	08.03.2017
Prüfdatum: *Date of Tests:*	15.03.2017 bis 25.04.2017
Prüfgutverbleib: *Remaining of test material:*	Das Prüfgut wird durch die MPA Darmstadt entsorgt. *The test material is disposed by MPA Darmstadt.*
Ausfertigungen: *Copies:*	Auftraggeber/MPA Darmstadt *Customer/MPA Darmstadt*

Staatliche Materialprüfungsanstalt Darmstadt
Kompetenzbereich Kunststoffe und Verbunde
Grafenstraße 2, 64283 Darmstadt

Seiten: *Pages:*	-7-
Tabellen: *Tables:*	-4-
Bilder: *Pictures:*	-0-
Anlagen: *Enclosures:*	-1-

Berichtsdatum: 13.07.2017 *Date of report:* Zeichen: K/Be *Reference:*

Leitung

i.A.
Dipl.-Ing. (FH) Ludwig Veith
Dr.-Ing. habil. D. Nickel

Sachbearbeiter

Dipl.-Ing. (FH) T. Beyrich

ANNEX 2

Test report K 17 1167 (continued)

1 Gegenstand der Untersuchung

Subject of the test

An den vom Auftraggeber bereitgestellten Kunststoffproben sollte folgendes bestimmt werden:

- Scher-Rheologische Messung im Platte/Platte Aufbau (Plattendurchmesser: 8 mm) im Frequenzbereich 0,02 Hz – 20 Hz bei verschiedenen Temperaturen
- Analyse der erhaltenen Messdaten, Erstellung von Masterkurven

The following tests should be conducted on the test parts with the above mentioned descriptions supplied by the customer:

- *Shear-Rheologic measurement in plate-plate geometry (plate diameter: 8 mm) in frequency range of 0,02 Hz to 20 Hz at different temperatures*
- *Analysis of the recorded data, generation of master curves*

2 Durchführung der Prüfung

Execution of the test

2.1 Rheologische Messung

Rheologic measurement

Probengeometrie: .... 8 mm Durchmesser, gestanzt
Geometry of the specimen .... 8 mm diameter, punched

Probenmaße in mm ca. .... 14x1,6 (Durchmesser x Wanddicke)
Measurements in mm approx. .... (diameter x wall thickness)

Anzahl Proben: .... jeweils 1
Number of specimen: .... 1 of each sheet

Probenvorbereitung: .... keine, direkt aus Verpackung
Pretreatment of specimen: .... none, directly taken from packing

Messgerät: .... Rheometer MCR 702 (Anton Paar)
Test equipment ....

Frequenzbereich: .... 0,02 Hz – 20 Hz
Frequency range: ....

Temperaturbereich: .... 70 °C bis -20 °C, in 5 K-Schritten
Temperature range: .... 70 °C to -20 °C in 5 K steps

Messmodus: .... Deformationsgesteuert
Test mode: .... deformation controlled

Deformation: .... 0,05 %
Deformation: ....

Normalkraft: .... 4 N - 10 N
Normal force: ....

Prüfdatum: .... 15.03.2017 – 26.04.2017
Date of tests ....

ANNEX 2

Test report K 17 1167 (continued)

3 Ergebnisse der Untersuchung

Test results

3.1 Rheologische Messung

Rheologic measurement

Die Rohdaten der Messungen sowie die Auswertung sind dem Bericht als Excel-Files angefügt.
Mit Hilfe von Verschiebungsfaktoren wurde jeweils eine Masterkurve für die Referenztemperatur von 20 °C, 30 °C, 35 °C sowie 40 °C angefertigt. Dabei werden nach dem TTS-Prinzip (Temperatur-Zeit-Verschiebung) die einzelnen Messkurven horizontal verschoben, bis alle Werte eine Kurve ergeben, welche über einen sehr hohen Frequenzbereich den Modulverlauf abbilden.
Ausgewählte Temperaturen und Frequenzen bzw. Zeitdauern sind in Tabelle 1 bis 4 gelistet, um eine Bestimmung der Steifigkeitsfamilie der Zwischenschicht nach prEN 16613-2017 zu ermöglichen.

The raw data of the measurements as well as the analysis are enclosed to the report as excel files.
With help of shift factors master curves for 20 °C, 30 °C, 35 °C and 40 °C for each sheet is calculated. As proposed by the time-temperature super-position, the single measurement data are shifted horizontal until all data points produce one graph. That graph shows the storage modulus in a very wide frequency range.
Selected temperatures and durations are listed in table 1 to 4 to enable an interlayer stiffness family determination according to prEN 16613:2017.

ANNEX 2

Test report K 17 1167 (continued)

Tabelle 1: Speichermodul und E-Modul für verschiedene Frequenzen sowie deren Kehrwert, berechnet aus den Daten der Masterkurve für 20 °C

Table 1: Storage moduli and Youngs moduli at different frequencies as well as the reciprocal values, determined from data from the master curve at 20 °C

Probe *specimen*	Frequenz [Hz] *Frequency [Hz]*	1/Frequenz *1/frequency*	Speichermodul [MPa] *Storage modulus [MPa]*	E-modul [MPa]* *Youngs modulus [MPa]**
Saflex DG41	3,3*10-1	3 s	287	859
	3,3*10-2	30 s	228	684
	1,7*10-2	1 min	210	631
	3,3*10-3	5 min	161	484
	1,7*10-3	10 min	140	419
	5,6*10-4	30 min	104	311
	2,8*10-4	1 h	83	247
	4,6*10-5	6 h	36	109
	2,3*10-5	12 h	24	71
	1,2*10-5	1 d	15	44
	2,3*10-6	5 d	4,4	13
	1,7*10-6	7 d	3,3	10
	5,5*10-7	21 d	1,7	5,2
	3,8*10-7	30 d	1,5	4,4
Saflex DG41 XC	3,3*10-1	3 s	271	813
	3,3*10-2	30 s	219	657
	1,7*10-2	1 min	202	605
	3,3*10-3	5 min	162	487
	1,7*10-3	10 min	144	432
	5,6*10-4	30 min	111	333
	2,8*10-4	1 h	91	273
	4,6*10-5	6 h	45	135
	2,3*10-5	12 h	31	94
	1,2*10-5	1 d	21	62
	2,3*10-6	5 d	6,3	19
	1,7*10-6	7 d	5,0	15
	5,5*10-7	21 d	2,2	6,7
	3,8*10-7	30 d	1,8	5,4

*E-Modul bestimmt mittels E=3G, wie vom Auftraggeber gefordert

** Youngs modulus determined as E=3G, according to customer*

ANNEX 2

Test report K 17 1167 (continued)

Tabelle 2: Speichermodul und E-Modul für verschiedene Frequenzen sowie deren Kehrwert, berechnet aus den Daten der Masterkurve für **30 °C**

Table 2: Storage moduli and Youngs moduli at different frequencies as well as the reciprocal values, determined from data from the master curve at 30 °C

Probe *specimen*	Frequenz [Hz] *Frequency [Hz]*	1/Frequenz *1/frequency*	Speichermodul [MPa] *Storage modulus [MPa]*	E-modul [MPa]* *Youngs modulus [MPa]**
Saflex DG41	3,3*10-1	3 s	98	295
	3,3*10-2	30 s	37	110
	1,7*10-2	1 min	24	72
	3,3*10-3	5 min	7,4	22
	1,7*10-3	10 min	4,5	13
	5,6*10-4	30 min	2,1	6,3
	2,8*10-4	1 h	1,5	4,4
	4,6*10-5	6 h	0,8	2,5
	2,3*10-5	12 h	0,8	2,3
	1,2*10-5	1 d	0,7	2,1
	2,3*10-6	5 d	0,6	1,8
	1,7*10-6	7 d	0,6	1,7
	5,5*10-7	21 d	0,5	1,6
	3,8*10-7	30 d	0,5	1,5
Saflex DG41 XC	3,3*10-1	3 s	97	292
	3,3*10-2	30 s	39	117
	1,7*10-2	1 min	26	79
	3,3*10-3	5 min	8,5	26
	1,7*10-3	10 min	5,0	15
	5,6*10-4	30 min	2,3	6,8
	2,8*10-4	1 h	1,5	4,4
	4,6*10-5	6 h	0,8	2,3
	2,3*10-5	12 h	0,7	2,0
	1,2*10-5	1 d	0,6	1,8
	2,3*10-6	5 d	0,5	1,6
	1,7*10-6	7 d	0,5	1,5
	5,5*10-7	21 d	0,5	1,4
	3,8*10-7	30 d	0,5	1,4

*E-Modul bestimmt mittels E=3G, wie vom Auftraggeber gefordert

** Youngs modulus determined as E=3G, according to customer*

ANNEX 2

Test report K 17 1167 (continued)

Tabelle 3: Speichermodul und E-Modul für verschiedene Frequenzen sowie deren Kehrwert, berechnet aus den Daten der Masterkurve für 35 °C

Table 3: Storage moduli and Youngs moduli at different frequencies as well as the reciprocal values, determined from data from the master curve at 35 °C

Probe *specimen*	Frequenz [Hz] *Frequency [Hz]*	1/Frequenz *1/frequency*	Speichermodul [MPa] *Storage modulus [MPa]*	E-modul [MPa]* *Youngs modulus [MPa]**
Saflex DG41	3,3*10-1	3 s	25	75
	3,3*10-2	30 s	4,6	14
	1,7*10-2	1 min	2,9	8,6
	3,3*10-3	5 min	1,2	3,6
	1,7*10-3	10 min	0,9	2,8
	5,6*10-4	30 min	0,8	2,3
	2,8*10-4	1 h	0,7	2,1
	4,6*10-5	6 h	0,6	1,8
	2,3*10-5	12 h	0,6	1,7
	1,2*10-5	1 d	0,5	1,6
	2,3*10-6	5 d	0,5	1,4
	1,7*10-6	7 d	0,4	1,3
	5,5*10-7	21 d		
	3,8*10-7	30 d		
Saflex DG41 XC	3,3*10-1	3 s	27	80
	3,3*10-2	30 s	5,0	15
	1,7*10-2	1 min	3,1	9,2
	3,3*10-3	5 min	1,2	3,6
	1,7*10-3	10 min	0,9	2,7
	5,6*10-4	30 min	0,7	2,1
	2,8*10-4	1 h	0,6	1,8
	4,6*10-5	6 h	0,5	1,6
	2,3*10-5	12 h	0,5	1,5
	1,2*10-5	1 d	0,5	1,4
	2,3*10-6	5 d	0,4	1,2
	1,7*10-6	7 d	0,4	1,2
	5,5*10-7	21 d		
	3,8*10-7	30 d		

*E-Modul bestimmt mittels E=3G, wie vom Auftraggeber gefordert

** Youngs modulus determined as E=3G, according to customer*

ANNEX 2

Test report K 17 1167 (continued)

Tabelle 4: Speichermodul und E-Modul für verschiedene Frequenzen sowie deren Kehrwert, berechnet aus den Daten der Masterkurve für **40 °C**

Table 4: Storage moduli and Youngs moduli at different frequencies as well as the reciprocal values, determined from data from the master curve at 40 °C

Probe *specimen*	Frequenz [Hz] *Frequency [Hz]*	1/Frequenz *1/frequency*	Speichermodul [MPa] *Storage modulus [MPa]*	E-modul [MPa]* *Youngs modulus [MPa]**
Saflex DG41	3,3*10-1	3 s	4,1	12
	3,3*10-2	30 s	1,1	3,3
	1,7*10-2	1 min	0,9	2,8
	3,3*10-3	5 min	0,7	2,1
	1,7*10-3	10 min	0,7	2,0
	5,6*10-4	30 min	0,6	1,8
	2,8*10-4	1 h	0,6	1,7
	4,6*10-5	6 h	0,5	1,4
	2,3*10-5	12 h	0,4	1,3
	1,2*10-5	1 d		
	2,3*10-6	5 d		
	1,7*10-6	7 d		
	5,5*10-7	21 d		
	3,8*10-7	30 d		
Saflex DG41 XC	3,3*10-1	3 s	4,3	13
	3,3*10-2	30 s	1,1	3,2
	1,7*10-2	1 min	0,9	2,6
	3,3*10-3	5 min	0,6	1,8
	1,7*10-3	10 min	0,6	1,7
	5,6*10-4	30 min	0,5	1,5
	2,8*10-4	1 h	0,5	1,5
	4,6*10-5	6 h	0,4	1,3
	2,3*10-5	12 h	0,4	1,2
	1,2*10-5	1 d		
	2,3*10-6	5 d		
	1,7*10-6	7 d		
	5,5*10-7	21 d		
	3,8*10-7	30 d		

*E-Modul bestimmt mittels E=3G, wie vom Auftraggeber gefordert

** Youngs modulus determined as E=3G, according to customer*

Keywords: Architectural, Families, Modulus, Stiffness, Saflex