STRATO glass interlayers

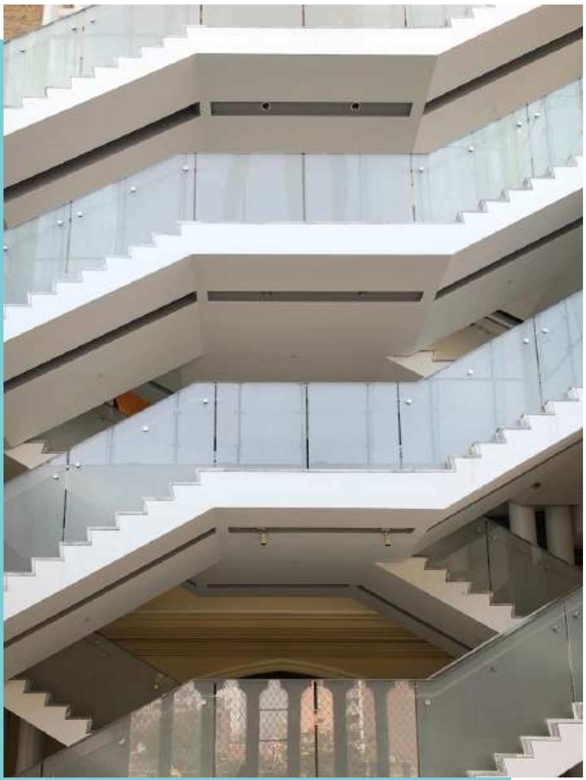
- STRATO® INTERLAYERS CHARACTERIZATION -

English | 0520-1

SATINAL

Introduction

In December 2019, the **EN 16612** and **EN 16613 standards** were designed and published and they are closely related to each other: in fact, the first one determines the **resistance of glass panes to lateral loads** by calculation, while the second one specifies the **mechanical properties of the interlayer** used to make laminated safety glass.



These standards have been under construction for years and their issue finally formalizes the importance of the choice of the interlayer. Therefore, they will replace or complete the individual regulations in the different European Union countries.

Selecting the type of film to be used is a very important decision: it determines the behaviour of laminated glass, whose **properties** depend on **the temperature** and **the loads** to which it is subjected.

This document provides technical data for STRATO® EVA interlayer in accordance with Annex A of EN 16613:2019 Standard Glass in building - Laminated glass and laminated safety glass - Determination of interlayer viscoelastic properties.

Note

The tests were carried out in a certified external laboratory.
The data provided in the following pages should not be used to establish specification limits or used alone as the basis of design; they are not intended to substitute for any testing you may need to conduct to determine for yourself the suitability of a specific material for your particular purposes. Final determination of suitability of any material or process and whether there is any infringement of patents is the sole responsibility of the user. Since Satinal cannot anticipate all variations in actual end-use conditions, Satinal makes no warranties and assumes no liability in connection with any use of this information.
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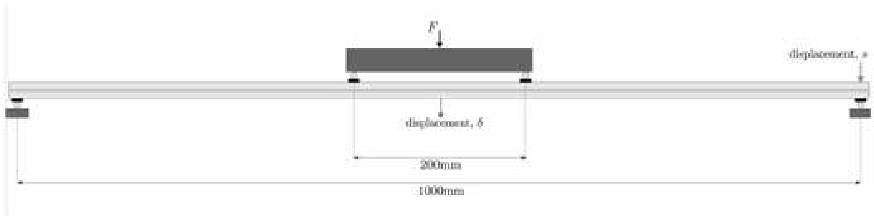
Samples identification

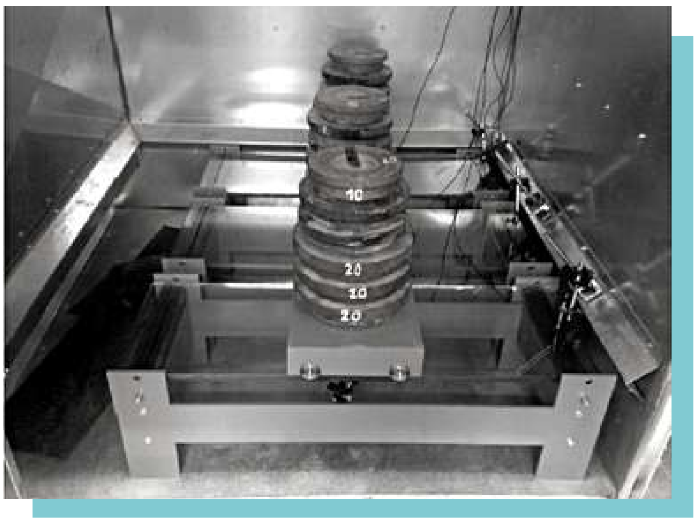
This document reports the **results of characterization tests of STRATO® EVA interlayer** produced by Satinal, in accordance with Annex A of EN 16613:2019 Standard.
Laminated glass samples measuring 1100 mm (43") in length and 360 mm (14") in width were tested and they consist of two 8 mm (5/16") float glass panes and one foil of 0,8 mm (.030") STRATO® EVA film.

Test procedure

The tests were carried out in accordance with the standard provided by ISO EN 1288-3:2016 (4-point bending test).



The samples were tested with a constant load of 1150 N and the displacements were monitored with an LVDT transducer positioned in the middle and one on the support (HBM WI10) in order to evaluate the lowering of the rubber between the support and the glass.



The data acquisition (with HBM spider 8 control unit) was performed with a sampling rate of at least 1 Hz for at least the first 4 hours of the test and then with a sampling rate of 1 minute.

The tests have been performed at the following temperatures: 20°C (68°F), 30°C (86°F), 40°C (104°F), 50°C (122°F), 60°C (140°F), controlled in Tecam chamber type M100A, S.N. N0133. For each temperature, 3 samples were tested.
The samples were kept in the chamber in a vertical position until the test temperature was reached.
The load was held the minimum time to ensure a constant displacement. In accordance with the standard, the displacement can be considered steady when the variation between two displacements acquired at a distance of four hours is less than 1%.

Test results

The samples tested showed a temperature-dependent behaviour, both in terms of movements observed and time needed to reach their stabilisation.

Test data analysis

Evaluation of the interlayer's Tangent Modulus of Elasticity (G)

The value of the Tangent Modulus of Elasticity was carried out in accordance with the standard (EN 16613:2019 §A.4) considering the maximum displacement.
In addition, it was evaluated the equivalent thickness of a monolithic glass (h_{mono}) using the following formula:

$$h_{mono} = \sqrt[3]{\frac{F(2L_S^3+L_B^3-3L_SL_B^2}{8E_Gbw} + \frac{60QL_s^4}{384E_Gbw}} \qquad (1)$$

in which:

F : applied force equal to 1150 N

Q: own weight of the element equal to 0.144N/m

L_S, L_B: distance between the supports and between the loading blades (1000 mm [39"] and 200 mm [8"] respectively)

E_G : elastic modulus of the assumed glass equal to 70000 MPa

b: beam width subject to load equal to 360 mm (14")

w: reduction measured during the test

The shear transfer coefficient is estimated by the ratio

$$\omega = \frac{h_{mono}^3 - \sum_k h_k^3}{12\sum_k (h_k h_{m;k}^2)} \tag{2}$$

in which:

h_k, $h_{m;k}$: are respectively the thicknesses of the single pane and the distance between the centre of gravity of the single k-th pane and the centre of gravity of the laminated section, equal to 8 mm (5/16") and 4.4 mm (11/64") respectively.

Last but not least, the Tangent Modulus of Elasticity G of the interlayer was evaluated by reversing the Wölfel-Bennison formula *(Ref. 3)*:

$$\omega = \frac{1}{1+9.6\frac{h_{int} E I_S}{G L_S^2 h_m^2}} \tag{3}$$

in which

h_k is the thickness of the selected interlayer equal to 0.8 mm (.030").

$$I_s = \sum_k (h_k h_{m;k}^2)$$

Please note that the coefficient 9.6 assumed in Eq.3 is the one commonly adopted *(Ref. 3)*, however in the complete analysis of Wölfel *(Ref. 4)* the coefficient for the assumed load condition is equal to 10.17.

In this analysis, it has been considered the value 9.6 which leads to lower Tangent Modulus of Elasticity values, and therefore more conservative.

Tables 2 and 3 show the displacement values, the resulting equivalent thickness h_{mono} (Eq.1), the shear transfer coefficient ω (Eq. 2), the tangent modulus of elasticity G and the modulus of elasticity E (evaluated as E=2(G+ν) with ν=0.5) measured at different loading times for the various temperatures considered (Figure 6).

Table 2 - Maximum displacement and equivalent thickness for several significant load moments

Loading time	Temperature °C					Temperature °C				
	20	30	40	50	60	20	30	40	50	60
	Displacement (mm)					hmono (mm)				
1 s	3,287	3,326	3,684	3,786	4,396	15,25	15,19	14,68	14,55	13,84
3 s	3,293	3,331	3,694	3,796	4,401	15,24	15,18	14,67	14,54	13,84
10 s	3,303	3,339	3,709	3,817	4,417	15,23	15,17	14,65	14,51	13,82
30 s	3,318	3,355	3,727	3,956	4,454	15,20	15,15	14,63	14,34	13,78
1 m	3,332	3,371	3,727	3,994	4,511	15,18	15,12	14,63	14,29	13,72
5 m	3,332	3,423	3,784	4,137	4,708	15,18	15,05	14,55	14,13	13,53
10 m	3,332	3,451	3,825	4,187	4,784	15,18	15,01	14,50	14,07	13,46
30 m	3,332	3,493	3,894	4,313	4,695	15,18	14,95	14,41	13,93	13,29
1 h	3,332	3,528	3,948	4,379	5,098	15,18	14,90	14,35	13,86	13,18
6 h	3,548	3,628	4,120	4,702	5,403	14,87	14,76	14,15	13,54	12,92
12 h	3,579	3,665	4,203	4,808	5,487	14,83	14,71	14,05	13,44	12,86
24 h	3,628	3,721	4,203	4,896	5,560	14,76	14,63	14,05	13,36	12,80

Table 3 - Shear transfer coefficient ω, tangent modulus of elasticity G and modulus of elasticity E at several significant load times

Loading time	Temperature °C					Temperature °C					Temperature °C				
	20	30	40	50	60	20	30	40	50	60	20	30	40	50	60
	ω					Shear Modulus | G (MPa)					Young Modulus | E (MPa)				
1 s	0,68	0,67	0,58	0,55	0,44	4,6	4,3	2,9	2,7	1,7	13,7	13,0	8,8	8,0	5,0
3 s	0,68	0,67	0,57	0,55	0,44	4,5	4,3	2,9	2,6	1,7	13,5	12,9	8,7	7,9	5,0
10 s	0,67	0,66	0,57	0,55	0,43	4,5	4,3	2,9	2,6	1,7	13,4	12,8	8,6	7,8	5,0
30 s	0,67	0,66	0,57	0,52	0,43	4,4	4,2	2,8	2,3	1,6	13,1	12,5	8,4	6,9	4,8
1 m	0,67	0,66	0,57	0,51	0,42	4,3	4,1	2,8	2,2	1,6	12,9	12,3	8,4	6,7	4,7
5 m	0,67	0,64	0,55	0,48	0,39	4,3	3,8	2,7	2,0	1,4	12,9	11,5	8,0	6,0	4,1
10 m	0,67	0,63	0,54	0,47	0,38	4,3	3,7	2,6	1,9	1,3	12,9	11,2	7,7	5,8	4,0
30 m	0,67	0,62	0,53	0,45	0,36	4,3	3,5	2,4	1,8	1,2	12,9	10,6	7,3	5,3	3,6
1 h	0,67	0,61	0,52	0,44	0,34	4,3	3,4	2,3	1,7	1,1	12,9	10,3	7,0	5,1	3,3
6 h	0,61	0,59	0,49	0,39	0,31	3,3	3,1	2,0	1,4	0,9	10,0	9,3	6,1	4,2	2,8
12 h	0,60	0,58	0,47	0,38	0,30	3,2	3,0	1,9	1,3	0,9	9,7	8,9	5,7	3,9	2,7
24 h	0,59	0,57	0,47	0,37	0,29	3,1	2,8	1,9	1,2	0,9	9,3	8,5	5,7	3,7	2,6

+ Insight

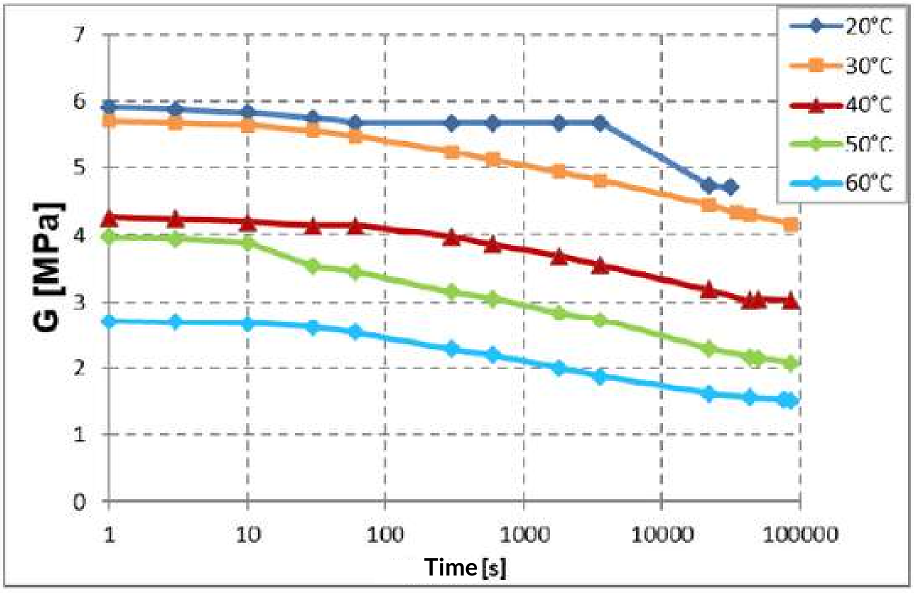
The modulus of elasticity (Young Modulus) and the Shear Modulus express the behaviour of the laminated glass under different types of stress.

*The **modulus of elasticity (Young Modulus)** expresses the **ratio between tension and deformation** in the case of mono-axial loading conditions and in the case of "elastic" behaviour of the material. It is defined as the ratio between the applied stress and the resulting deformation.*

*The **Shear Modulus** expresses instead the tangential **stress-strain ratio**.*

*According to the data obtained in the Young Modulus, it has been calculated the **ω factor** that expresses the **matching characteristics** of the interlayer. This factor can change between 0 (no matching) and 1 (full matching).*

Figure 6 - Shear transfer coefficient ω and tangent modulus of elasticity G at different temperatures and for different load durations



Master curves

The time-temperarure equivalence, a well-known phenomenon observed in stress-relaxation tests on polymers, can be used to draw up a general master curve for a specific reference temperature T, starting from observations at different temperatures.
To generate a master curve for a specific reference temperature T, the tangent modulus of elasticity curves G vs time (Figure 6) must be translated horizontally, keeping the position of the reference curve fixed.

The horizontal shift value can be estimated in relation to temperature by calculating the shift factor a_{To} using the renowned Williams and Ferry report *(Ref. 5)*.

$$\log a_{to} = \frac{-C_1(T - T_o)}{C_2 + (T - T_o)}$$

in which T_0 is the reference temperature, while C_1 and C_2 are two coefficients considered respectively equal to 17.44 and 51.6.

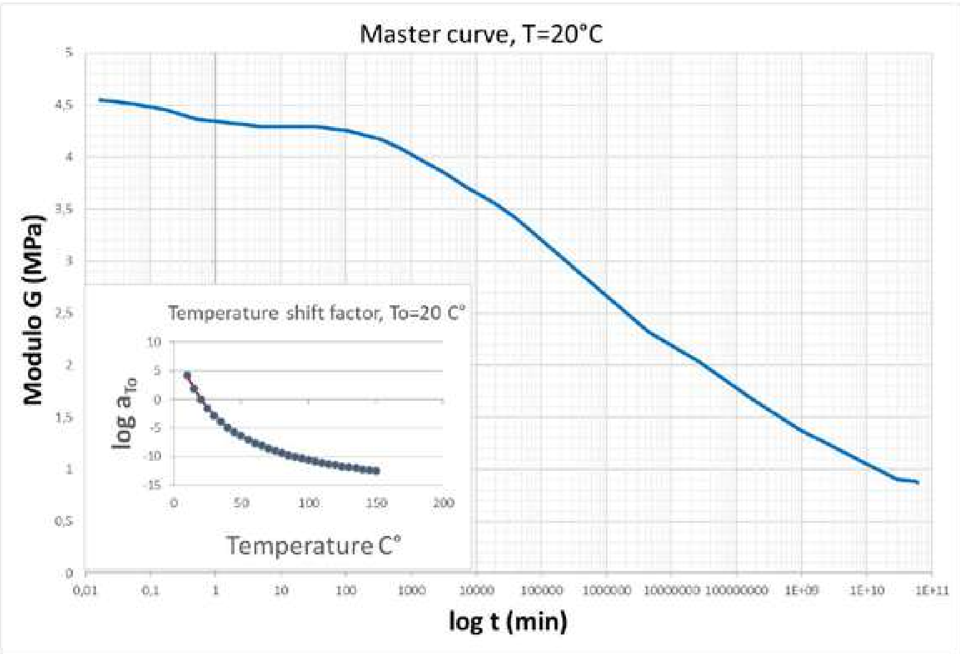
The amount of horizontal shift - to which each curve must be subjected - can be drawn as a function of temperature, as shown in Figure 7 for the reference temperature T=20°C (68°F).

In this way the horizontal shift of each G(t) curve represented (Figure 6) is determined by applying the following equation

$$\log t_1 = \log t - \log a_{to}$$

in which t is the original time scale, while t_1 is the new time scale shifted. In this way it is possible to obtain the master curves at different temperatures.

Figure 7 - Master curve corresponding to the temperature of T=20°C and relative trend of the shift factor with temperature variation.



The Figure 8 shows the master curves obtained.

Figure 8 - Master curves at different temperatures T

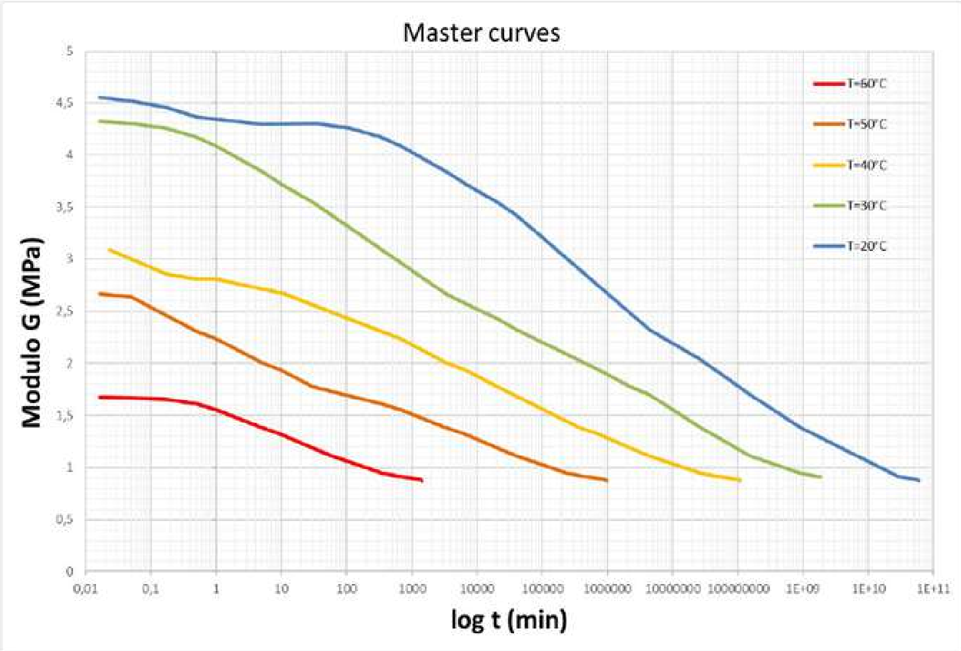


Table 4 shows the stiffness family of the interlayer evaluated according to Annex A of the UNI EN16613 standard.

Table 4 – Stiffness family of STRATO® EVA interlayer

Loading conditions	Time	Temperature °C	Stiffness family
1. Wind gust load (Mediterranean areas)	3 sec	35	1
2. Wind gust load (other regions)	3 sec	20	1
3. Wind Storm load (Mediterranean areas)	10 min	35	2
4. Wind Storm load (other regions)	10 min	20	1
5. Balustrade loads, no crowds (e.g. building use categories A, B1, C1, E by EN 1991-1-1)	30 sec	30	1
6. Balustrade loads, crowds	5 min	30	1
7. Maintenance loads	30 min	40	2
8. Snow load – external canopies, roofs of unheated buildings	3 week	20	1
9. Snow load – roofs of heated buildings	5 days	20	2
10. Climatic loads – IGU summer	6 h	40	2
11. Climatic loads – IGU winter	12 h	20	1
12. Permanent	50 years	60	-

Insight

The behaviour of laminated glass subjected to different types of stress, determines the ***stiffness family of the interlayer used.***
EN 16613 Standard has established three types of families 0,1 and 2 (the latter representing the stiff interlayer) and 12 load conditions (listed in Table 4).

Reference

[1] UNI EN 16613:2019: Glass in building - Laminated glass and laminated safety glass. Determination of interlayer mechanical properties, issue March 2020.

[2] UNI EN 1288-3:2001, Glass in building - Determination of the bending strength of glass - Part 3: Test with specimen supported at two points (four point bending), Italian National Unification Institution (UNI), 2001.

[3] National Research Council, CNR-DT 210/2013, Instructions for the design, execution and control of buildings with glass structural elements, 2013.

[4] Wölfel E., Elastic Composite: An Approximation Solution and its Application Possibilities, Stahlbau, 6: 173–180, 1987

[5] Ferry, J.D., Viscoelastic Properties of Polymers, 3rd ed., JW, NY, 1980.

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