Mechanical models for Saflex® interlayers in structural glass design

Saflex® is a plasticized polyvinyl butyral (PVB) interlayer produced by Eastman Chemical Company. These interlayers are bonded through a heat and pressure process to two or more pieces of glazing to produce laminates with impact and glass containment properties. Laminated glass with Saflex interlayers can be classified as safety glazing in accordance with, but not limited to, various regulations such as ANSI Z26.1, ANSI Z97.1, AS/NZS 2208; CNS 1183, CPSC 16 CFR 1201, EN 12600 and ISO 29584.

The generic physical and mechanical properties of Saflex Clear, Saflex Acoustic and Saflex Structural PVB interlayers are provided in their Product Technical Datasheets (PTS). The interlayer shear 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, including all Saflex formulations, are a strong function of temperature and load duration and are available as tabular values in the Saflex PTS.

For advanced engineering modelling, it may be advantageous to have the material properties available as a continuous mathematical function, rather than a tabular format. This document provides such functions for Saflex Clear, Saflex Acoustic and Saflex Structural. A full discussion, description and information on how these models were developed and validated is outside of the scope of this document but can be found in references [1] and [2]. An extensive, generic scientific background is provided in [3].

A representative model Prony series comprising 10-11 elements was chosen to balance accuracy with practicality as a model for shear relaxation modulus G(t). This function is a mathematical representation of the molecular motion taking place in the polymer, which can be described mechanically as a series of Maxwell models:

$$G(t) = G_\infty + \sum_{i=1}^{n} G_i e^{-t/\tau_i}$$

$$\tau_i = {}^{\eta_i}/_{G_i} \text{ and } Gi = {}^{g_i}/_{G_0}$$

in which the modulus G_i reflects the relative magnitude of each process while the relaxation time τ_i indicates its timescale. Curve fitting was optimized over the number of elements disregarding the exact values of the relaxation time, which were later interpolated to more rounded relaxation times, while reviewing retainment of fit. For all products, a temperature shift function was developed based on the WLF equation of type:

$$log_{10} a_\tau(T, T_{ref}) = -\frac{C_1 * (T - T_{ref})}{C_2 + T - T_{ref}}$$

For each Prony series, values are provided for g_i, τ_i, G_0 (modulus upper limit) G_∞ (modulus lower limit) and fitting constants C_1 and C_2. The models can be evaluated for any temperature and duration, as long as the model limitations as discussed in [1] are respected. The models for Saflex Clear and Saflex Structural can be considered fully validated for a temperature range between 10°C and 60°C, and durations from 3 seconds up to 1 month. For the acoustic tri-layer product (Saflex Acoustic), the validated range is more limited to durations of up to 1 hour and temperatures up to 40°C.

Material Models for Saflex interlayers

The Prony series developed for Saflex Clear is represented in Table 1, for Saflex Acoustic in Table 2 and Saflex Structural in Table 3, along with the WLF parameters C1 and C2.

Table 1. Model parameters for the evaluation shear relaxation modulus G(t,T) for Saflex Clear R series

	G_0 = 97.37 MPa	G_∞= 0.008 MPa
	T_{ref} = 20 °C	C1 = 33.2
		C2 = 212.4
i	**relaxation time**	**g_i (G_i/G_0)**
	(s)	
1	1.00E-02	0.2995
2	1.00E-01	0.2997
3	1.00E+00	0.2790
4	1.00E+01	0.0912
5	1.00E+02	0.0207
6	1.00E+03	0.0044
7	1.00E+04	0.0013
8	1.00E+05	0.0006
9	1.00E+06	0.0008
10	1.00E+07	0.0028

Table 2. Model parameters for the evaluation shear relaxation modulus G(t,T) for Saflex Acoustic QS

	G_0 = 368 MPa	G_∞= 0 MPa
	T_{ref} = 20 °C	C1 = 35.9
		C2 = 266.3
i	**relaxation time**	**g_i (G_i/G_0)**
	(s)	
1	1.000E-09	0.2029
2	1.000E-08	0.2030
3	1.000E-06	0.2597
4	1.000E-04	0.2331
5	1.000E-03	0.0672
6	1.000E-02	0.0236
7	1.000E+00	0.0042
8	1.000E+01	0.0035
9	1.000E+02	0.0015
10	1.000E+04	0.0004
11	1.000E+06	0.0004

Table 3. Model parameters for the evaluation shear relaxation modulus G(t,T) for Saflex Structural (Saflex DG and DG XC) interlayers.

	G_0 = 576 MPa	G_∞= 0.23 MPa
	T_{ref} = 20 °C	C1 = 21.3
		C2 = 66.0
i	relaxation time	g_i (G_i/G_0)
	(s)	
1	1.000E-01	0.1713
2	1.000E+00	0.1960
3	1.000E+01	0.2101
4	1.000E+02	0.2054
5	1.000E+03	0.1503
6	1.000E+04	0.0543
7	1.000E+05	0.0101
8	1.000E+06	0.0018
9	1.000E+07	0.0005
10	1.000E+10	0.0003

References

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