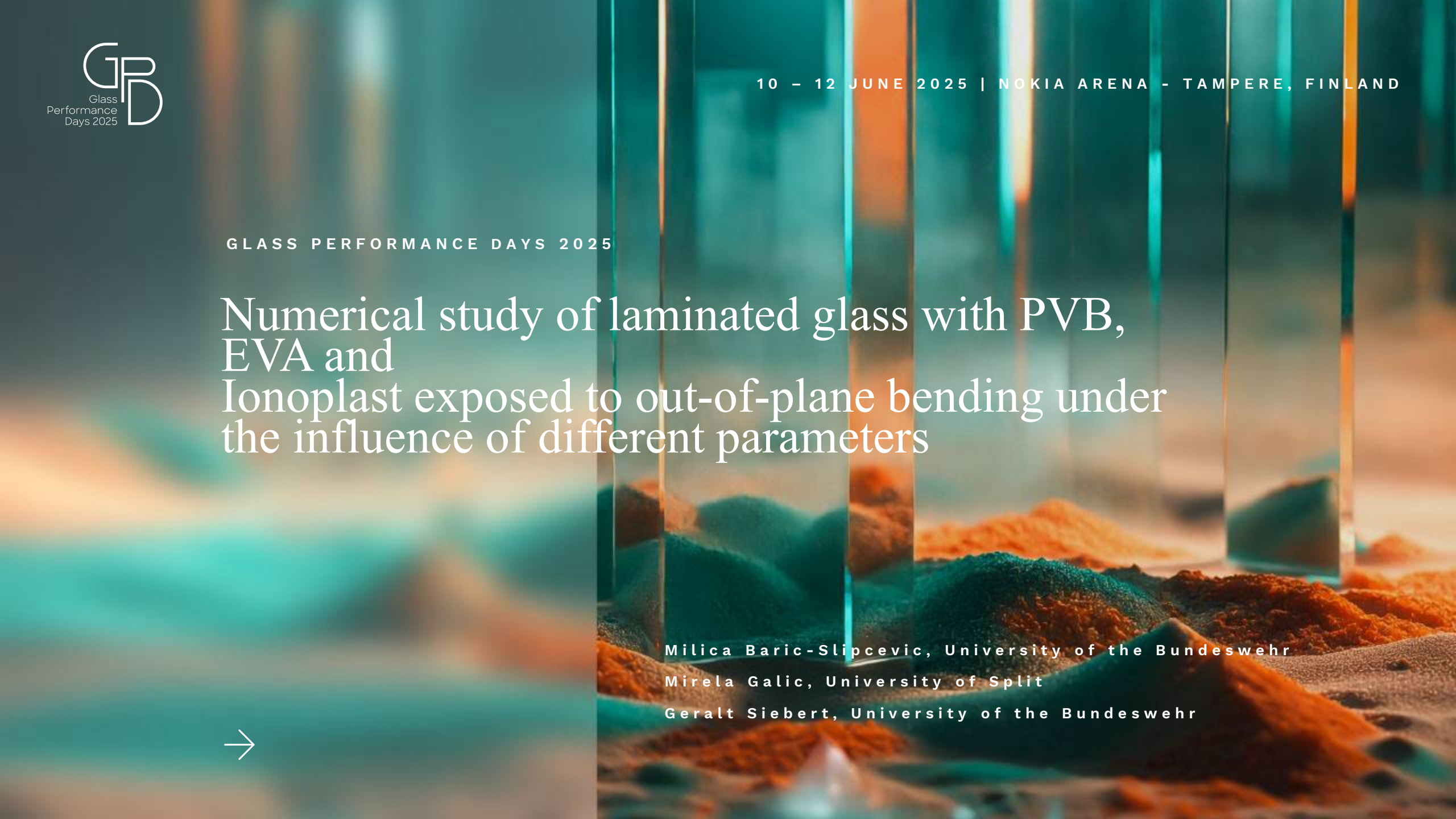

Glass Performance Days 2025

10 – 12 JUNE 2025 | NOKIA ARENA - TAMPERE, FINLAND

GLASS PERFORMANCE DAYS 2025

Numerical study of laminated glass with PVB, EVA and Ionoplast exposed to out-of-plane bending under the influence of different parameters

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INTRODUCTION

- numerical analyses of laminated glass panels exposed to four-point bending
- the relationship between the load duration, temperature, and thickness of the interlayer compared to the maximal displacement and tension stress in the bottom glass plate
- ethylene vinyl acetate (EVA), polyvinyl butyral (PVB) and Ionoplast
- EVA was done in this research and compared with results for the PVB and Ionoplast from the literature

METHODOLOGY

- Structural analysis was performed in Ansys software
- EVA – load duration and temperature dependent
- Glass – linear elastic
- 3 different glass setups: 6+10 mm, 10+6 mm and 8+8 mm
- 2 different interlayer thicknesses 0,76 mm and 1,52 mm
- Models have a span of 950x330 mm
- Load 1kN – 15,151 N/mm
- Stresses in the bottom plate and deflection were observed
- Contact between glass and interlayer is an absolute bond

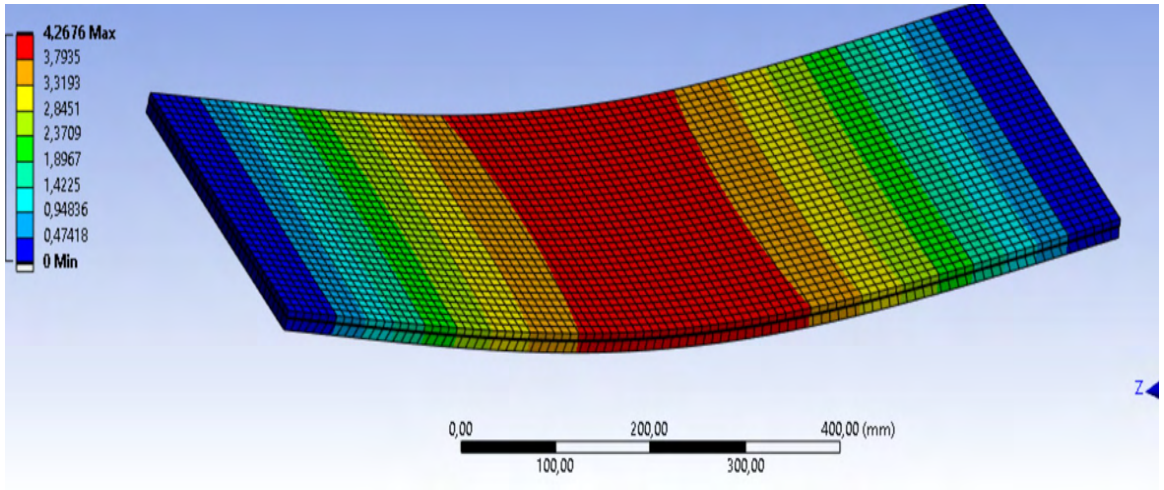
		Lastdauer						
E-Modul [MPa]		1s	3s	1 min	1h	1Tag	1 Monat	10 Jahre
Temperatur	10°C	14,817	13,507	10,756	8,314	6,870	5,616	4,137
	20°C	10,298	9,545	7,969	6,165	5,154	4,131	2,911
	24°C	9,115	8,561	7,131	5,594	4,497	3,640	2,513
	30°C	7,756	7,234	5,985	4,616	3,822	2,952	1,874
	40°C	4,733	4,409	3,649	2,680	1,953	1,236	0,523
	50°C	2,844	2,618	1,927	1,104	0,606	0,329	0,134
	60°C	1,315	1,131	0,653	0,308	0,149	0,134	0,134
	70°C	0,414	0,341	0,179	0,134	0,134	0,134	0,134
	80°C	0,168	0,136	0,134	0,134	0,134	0,134	0,134

Bericht Folienwerk Wolfen
Bestimmung Des Zeitabhängigen
E-moduls Von Eva-verkapselungsmaterialien

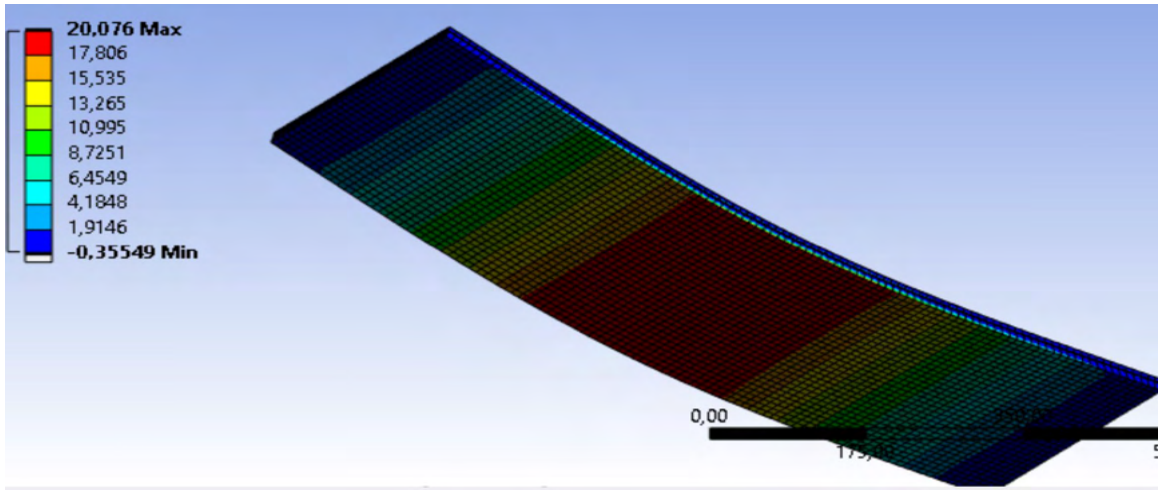
Properties	Middle value	Interval
Glass density	$\rho = 2500$ kg/m^3	2250–2750 kg/m^3
Young's modulus	E = 70,000 MPa	63,000–77,000 MPa
Poisson number	$\mu = 0.23$	0.20–0.25

Mechanical properties of the glass according to EN 16612

NUMERICAL MODEL



Deflection in mm for the 6+1,52+10 mm



Stress in MPa for the bottom plate for the 6+1,52+10 mm

RESULTS WITH EVA

Deflection 10+1,52+6 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	2,98	3,4545	3,703	4,1176
24	3,43	4,0217	4,3325	4,9014
30	3,61	4,2128	4,5911	5,2714
40	4,27	5,2027	5,8566	6,836

Deflection 6+1,52+10 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	2,98	3,4521	3,7001	4,1138
24	3,43	4,0181	4,328	4,8945
30	3,61	4,2086	4,5856	5,2621
40	4,27	5,1939	5,8418	6,8026

Bottom panel - stress 10+1,52+6 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	13,8	14,234	14,458	14,852
24	14,214	14,76	15,363	17,858
30	14,373	14,944	16,5	19,469
40	15,097	19,171	22,003	26,183

Bottom panel - stress 6+1,52+10 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	16,222	17,65	18,39	19,617
24	17,584	19,331	20,255	21,94
30	18,11	19,9	21,019	23,039
40	20,076	22,836	24,806	27,847

RESULTS WITH EVA

Deflection 10+0,76+6 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	2,80	3,1091	3,3134	3,6194
24	3,09	3,5176	3,7823	4,2548
30	3,22	3,664	3,9902	4,5878
40	3,71	4,5063	5,1647	6,2955

Deflection 6+0,76+10 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	2,77	3,0905	3,2702	3,5866
24	3,07	3,5012	3,7464	4,2289
30	3,19	3,6483	3,9571	4,5646
40	3,69	4,4931	5,1418	6,2715

Bottom panel - stress 10+0,76+6 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	14,175	14,443	14,609	14,858
24	14,429	14,77	14,979	15,377
30	14,529	14,886	15,152	16,244
40	14,921	15,883	18,803	23,769

Bottom panel - stress 6+0,76+10 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	15,878	16,854	17,386	18,327
24	16,788	18,075	18,795	20,195
30	17,153	18,508	19,407	21,172
40	18,629	20,964	22,851	26,222

RESULTS WITH EVA

Deflection 8+1,52+8 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	3,13	3,6883	3,9689	4,4696
24	3,65	4,3553	4,72	5,42
30	3,86	4,5833	5,0339	5,8788
40	4,65	5,793	6,6155	7,8872

Deflection 8+0,76+8 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	2,86	3,2419	3,4547	3,8672
24	3,21	3,7216	4,0149	4,624
30	3,35	3,8953	4,2662	5,0284
40	3,94	4,9129	5,7198	7,1842

Bottom panel - stress 8+1,52+8 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	15,62	16,856	17,478	18,579
24	16,775	18,329	19,132	20,672
30	17,233	18,831	19,821	21,694
40	18,971	21,503	23,376	26,319

Bottom panel - stress 8+0,76+8 (mm)				
Temp. C°	EVA			
	1 min	24 h	1 month	10 years
10	15,442	16,279	16,742	17,627
24	16,208	17,314	17,944	19,243
30	16,522	17,687	18,481	20,105
40	17,781	19,858	21,576	24,805

RESULTS WITH PVB AND IONOPLAST

Deflection 10+1.52+6 (mm)								
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	1.835	2.077	3.909	5.403	1.837	1.843	1.847	1.852
25	1.858	3.963	5.245	5.827	1.848	1.872	1.907	1.971
30	2.040	5.234	5.724	6.500	1.866	1.931	2.279	2.732
40	4.860	6.015	6.778	7.279	2.000	2.858	3.158	3.274

Bottom panel - stress - 10+1.52+6 (MPa)								
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	12.614	12.910	14.676	19.998	12.605	12.612	12.621	12.624
25	12.641	14.731	19.339	21.891	12.620	12.652	12.703	12.783
30	12.886	19.266	21.429	24.810	12.646	12.732	13.159	13.615
40	17.619	22.710	26.000	28.180	12.822	13.733	14.000	14.113

Deflection 10+0.76+6 (mm)					Deflection 10+0.89+6 (mm)			
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	2.064	2.210	3.457	4.736	1.978	1.981	1.984	1.988
25	2.077	3.447	4.561	5.157	1.984	2.000	2.023	2.065
30	2.181	4.525	5.031	5.907	1.996	2.038	2.266	2.576
40	4.177	5.323	6.241	6.922	2.083	2.664	2.881	2.967

Bottom panel - stress - 10+0.76+6 (MPa)					Bottom panel - stress - 10+0.89+6 (MPa)			
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	13.508	13.630	14.740	16.885	13.133	13.138	13.140	13.145
25	13.516	14.725	16.105	18.756	13.142	13.161	13.185	13.232
30	13.605	15.964	18.195	22.075	13.157	13.203	13.481	13.813
40	15.320	19.515	23.544	26.557	13.256	13.898	14.103	14.182

Galić et.al, Parametric Analyses of the Influence of Temperature, Load Duration, and Interlayer Thickness on a Laminated Glass Structure Exposed to Out-of-Plane Loading // Crystals 2022, 12, 838. https://doi.org/10.3390/cryst12060838

RESULTS WITH PVB AND IONOPLAST

Deflection 6+1.52+10 (mm)								
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	1.835	2.077	3.907	5.402	1.837	1.843	1.847	1.852
25	1.858	3.962	5.242	5.824	1.848	1.872	1.907	1.971
30	2.042	5.231	5.720	6.493	1.866	1.931	2.279	2.732
40	4.855	6.010	6.768	7.260	2.001	2.857	3.158	3.274

Bottom panel - stress - 6+1.52+10 (MPa)								
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	12.362	13.416	19.086	23.483	12.365	12.403	12.429	12.459
25	12.506	19.249	23.014	24.730	12.439	12.579	12.761	13.044
30	13.292	22.984	24.426	26.707	12.549	12.873	14.176	15.649
40	21.833	25.279	27.528	29.051	13.166	16.037	16.947	17.291

Deflection 6+0.76+10 (mm)					Deflection 6+0.89+10 (mm)			
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	2.063	2.203	3.421	4.707	2.022	2.026	2.029	2.032
25	2.076	3.440	4.540	5.133	2.029	2.045	2.068	2.110
30	2.180	4.520	5.013	5.888	2.041	2.083	2.312	2.624
40	4.174	5.317	6.230	6.907	2.129	2.713	2.931	3.018

Bottom panel - stress - 6+0.76+10 (MPa)					Bottom panel - stress - 6+0.89+10 (MPa)			
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	13.400	14.093	17.921	21.643	13.218	13.247	13.267	13.290
25	13.498	17.992	21.160	22.867	13.273	13.376	13.509	13.712
30	14.006	21.102	22.528	25.042	13.354	13.589	14.504	15.552
40	20.108	23.399	26.025	27.994	13.797	15.833	16.507	16.767

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RESULTS WITH PVB AND IONOPLAST

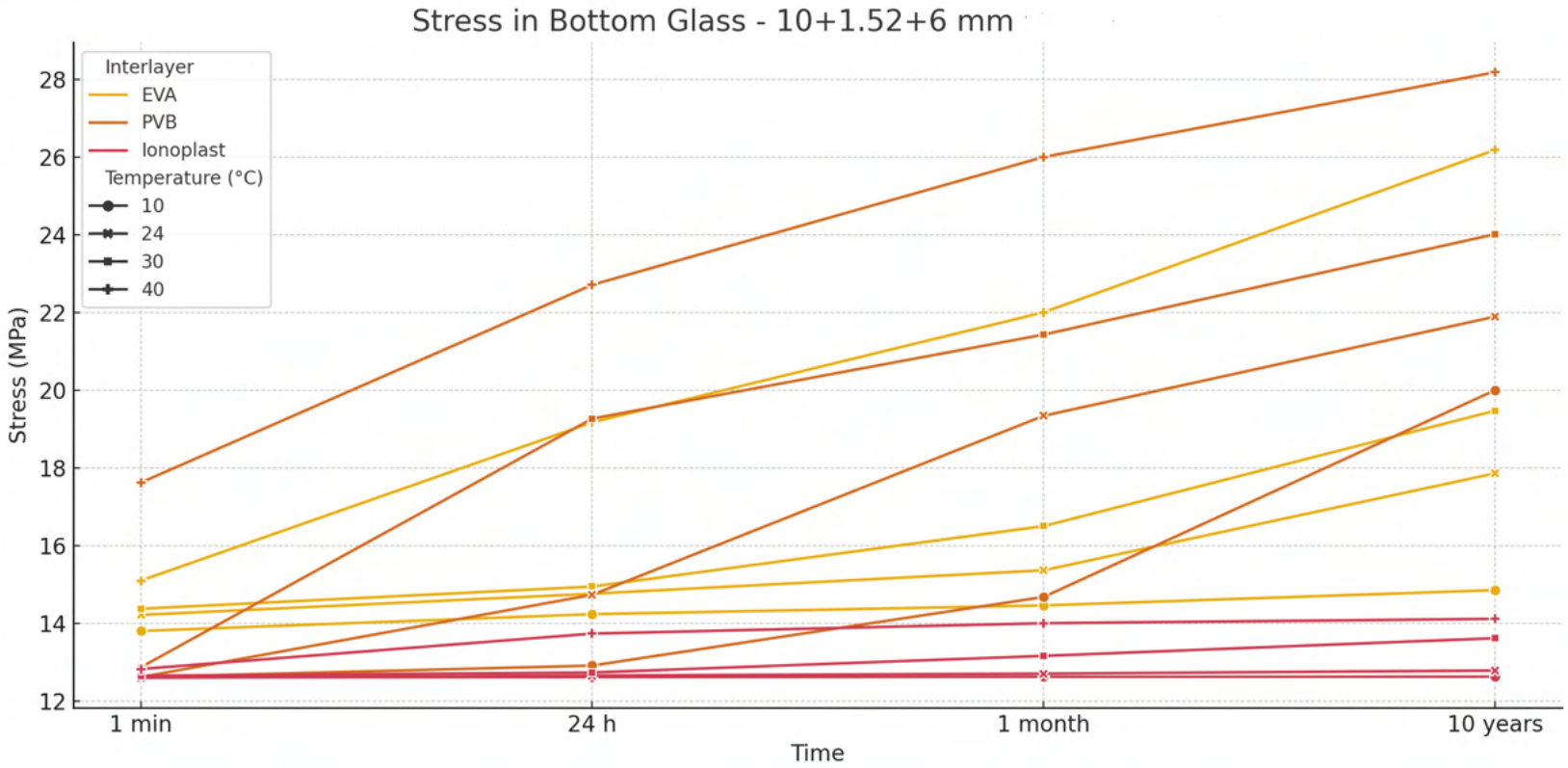
Deflection 8+1.52+8 (mm)								
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	1.812	2.084	4.223	6.061	1.815	1.821	1.258	1.831
25	1.837	4.265	5.851	6.597	1.827	1.852	1.892	1.963
30	2.040	5.827	6.458	7.470	1.846	1.918	2.308	2.822
40	5.356	6.826	7.834	8.501	1.996	2.966	3.314	3.449

Bottom panel - stress - 8+1.52+8 (MPa)								
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	12.361	13.225	18.121	22.108	12.360	12.390	12.409	12.435
25	12.471	18.217	21.654	23.227	12.417	12.528	12.675	12.907
30	13.111	21.603	22.975	25.171	12.504	12.767	13.872	15.103
40	20.580	23.776	25.973	27.534	13.010	15.424	16.212	16.514

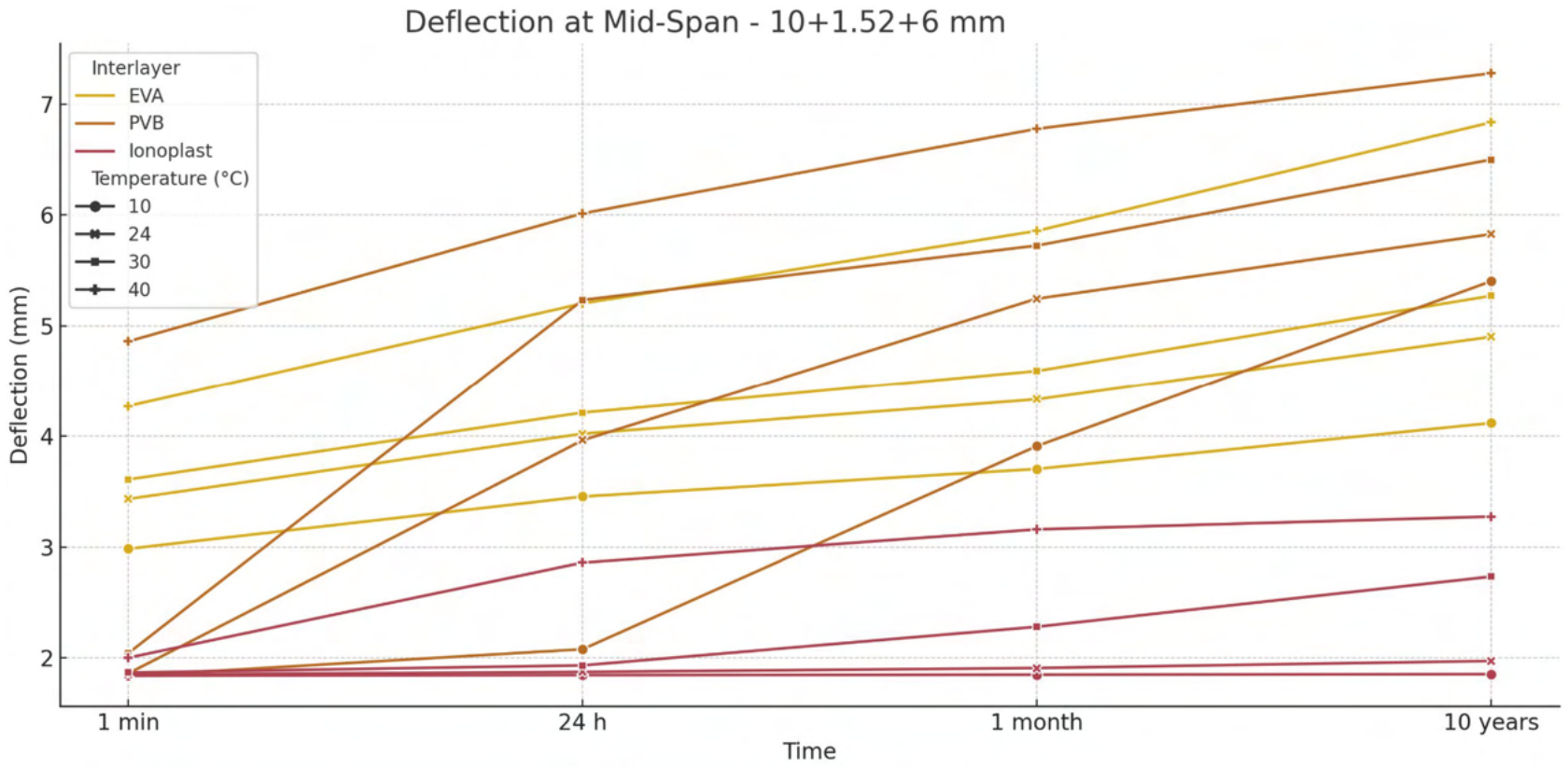
Deflection 8+0.76+8 (mm)					Deflection 8+0.89+8 (mm)			
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	2.049	2.211	3.644	5.197	2.007	2.011	2.014	2.019
25	2.063	3.460	4.979	5.721	2.015	2.032	2.058	2.105
30	2.018	4.939	5.564	6.681	2.028	2.075	2.333	2.688
40	4.514	5.937	7.119	8.027	2.125	2.789	3.042	3.142

Bottom panel - stress - 8+0.76+8 (MPa)					Bottom panel - stress - 8+0.89+8 (MPa)			
Temp	PVB				IONOPLAST			
(°C)	1min	24h	1 month	10 years	1 min	24h	1 month	10 years
10	13.385	13.931	17.225	20.514	13.200	13.222	13.236	13.258
25	13.456	17.224	20.060	21.615	13.241	13.321	13.425	13.590
30	13.850	19.971	21.285	23.633	13.303	13.490	14.244	15.131
40	19.071	22.057	24.554	26.474	13.659	15.365	15.926	16.147

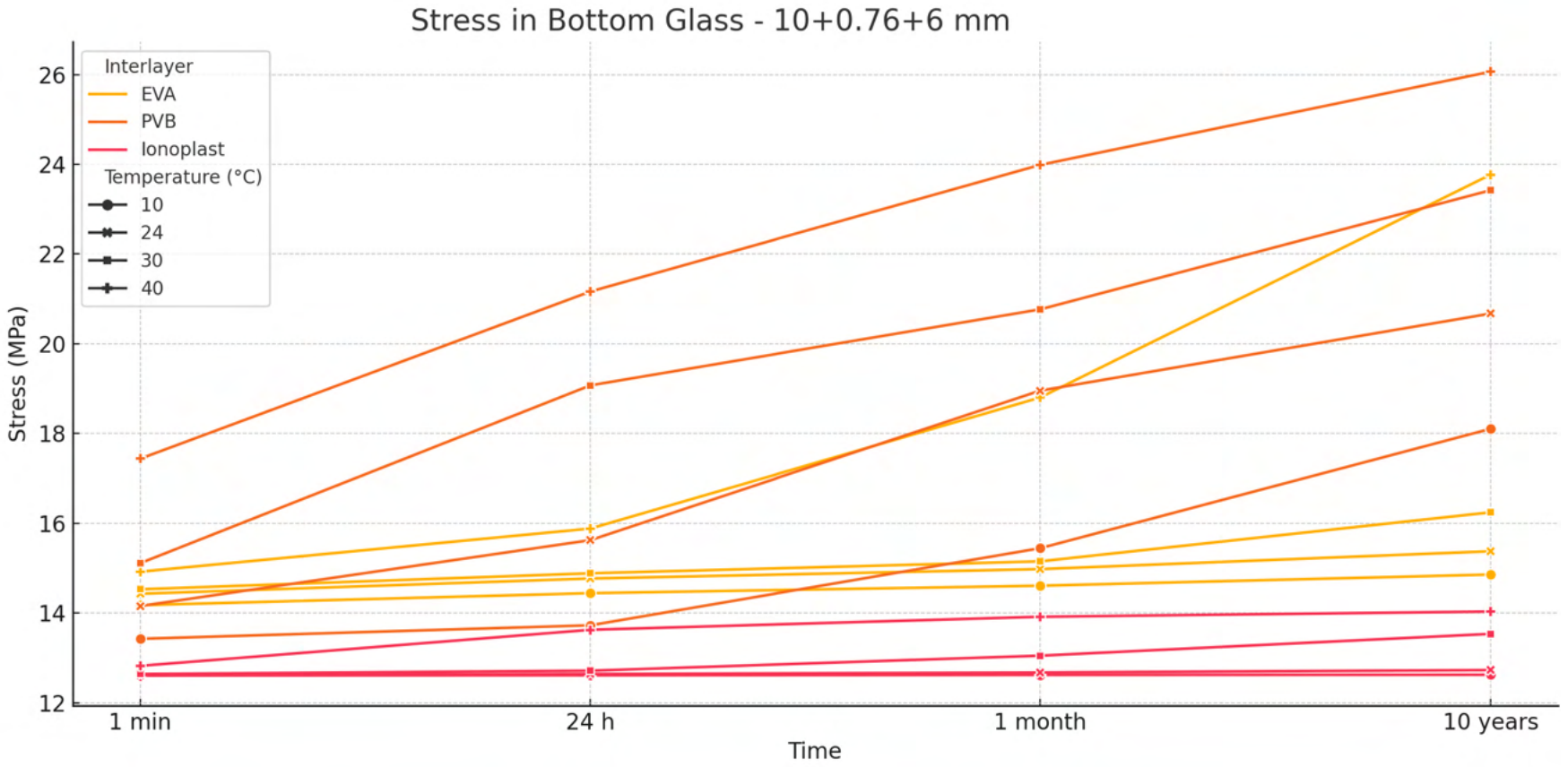
Galić et.al, Parametric Analyses of the Influence of Temperature, Load Duration, and Interlayer Thickness on a Laminated Glass Structure Exposed to Out-of-Plane Loading // Crystals 2022, 12, 838. https://doi.org/10.3390/cryst12060838



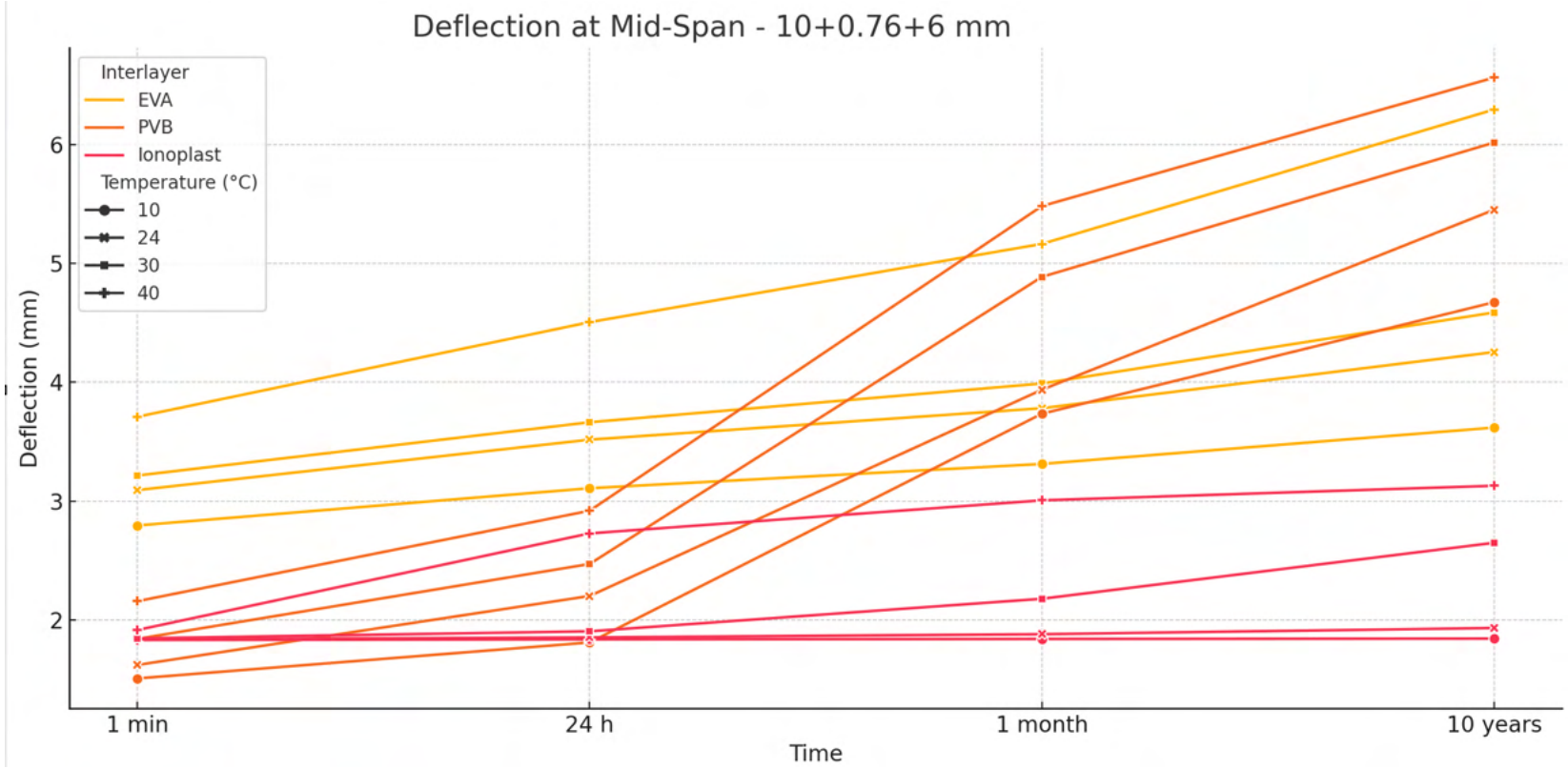
- EVA shows a increase in stress over time and temperature, indicating softening but still offering structural support
- PVB has a more pronounced rise in stress, especially at higher temperatures and longer durations — it degrades more with time and heat
- Ionoplast maintains almost constant stress regardless of time or temperature — the stiffest and most stable interlayer here



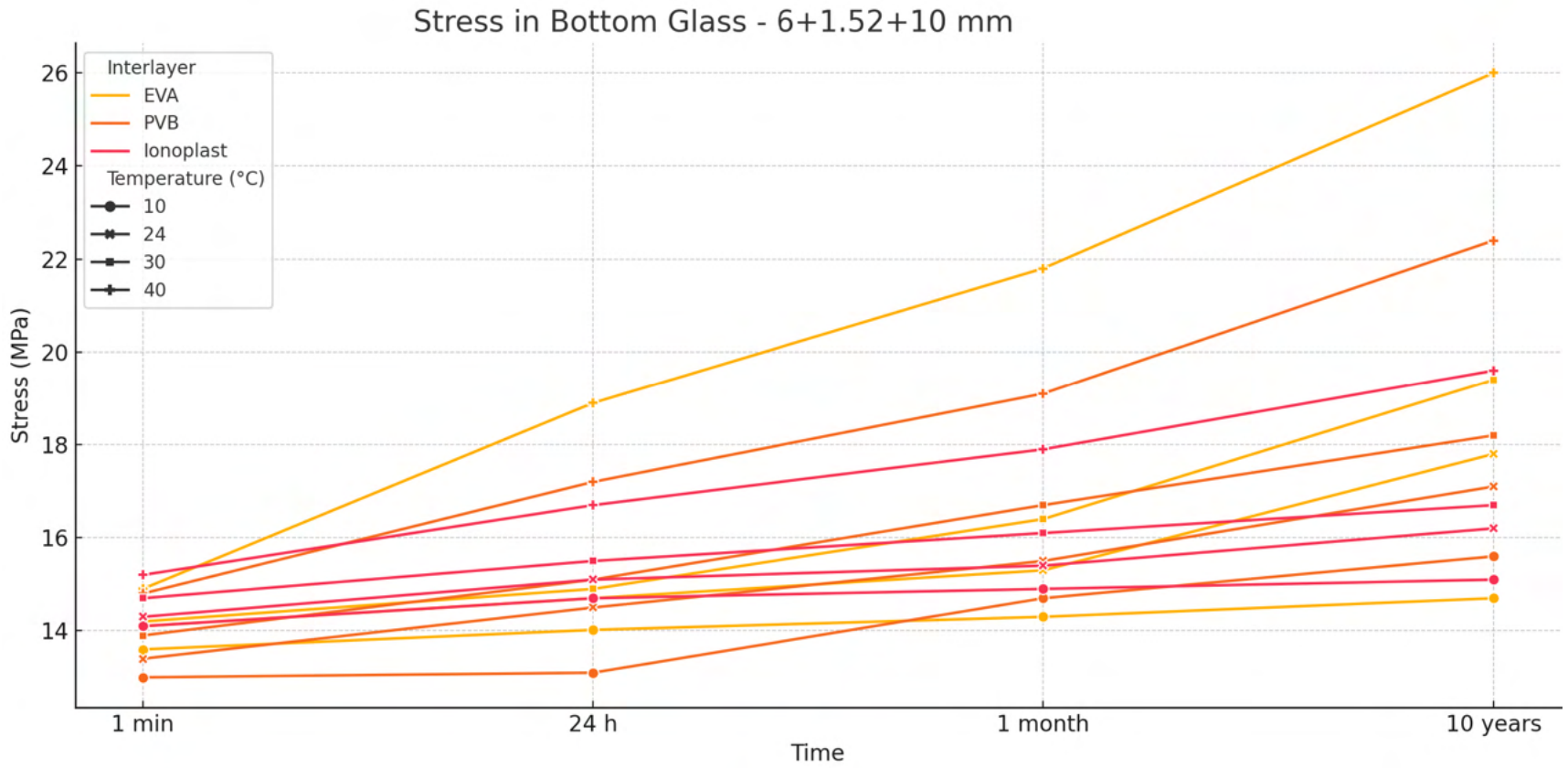
- Ionoplast exhibits the lowest deflection across all conditions — confirming its high stiffness
- PVB shows increased deflection with time and temperature — indicating the weakest structural contribution over long durations
- EVA behaves between Ionoplast and PVB — with moderate creep and temperature sensitivity



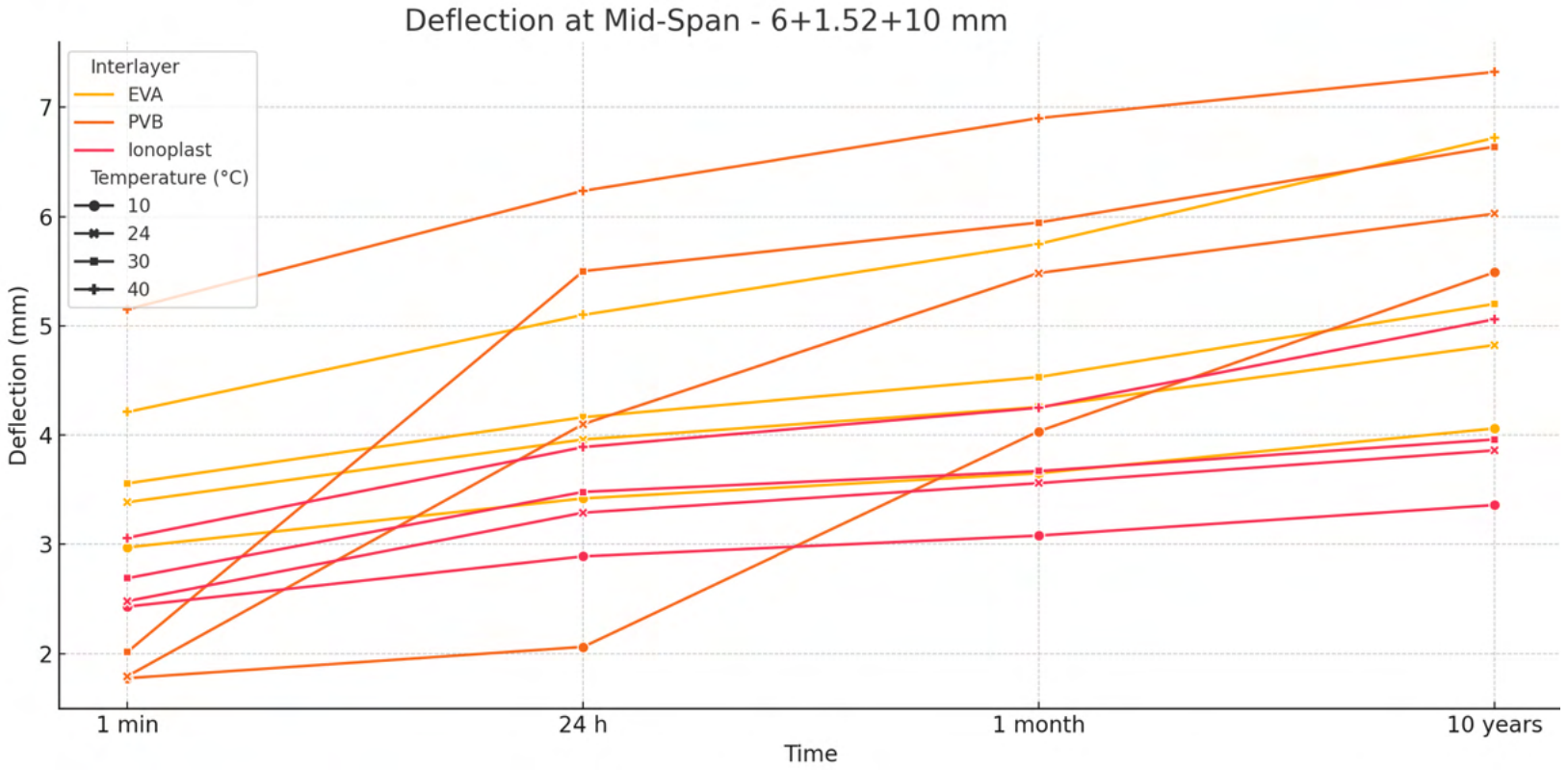
- Ionoplast keeps stress levels low, even after 10 years at 40 °C
- PVB and EVA show rising stress over time and heat



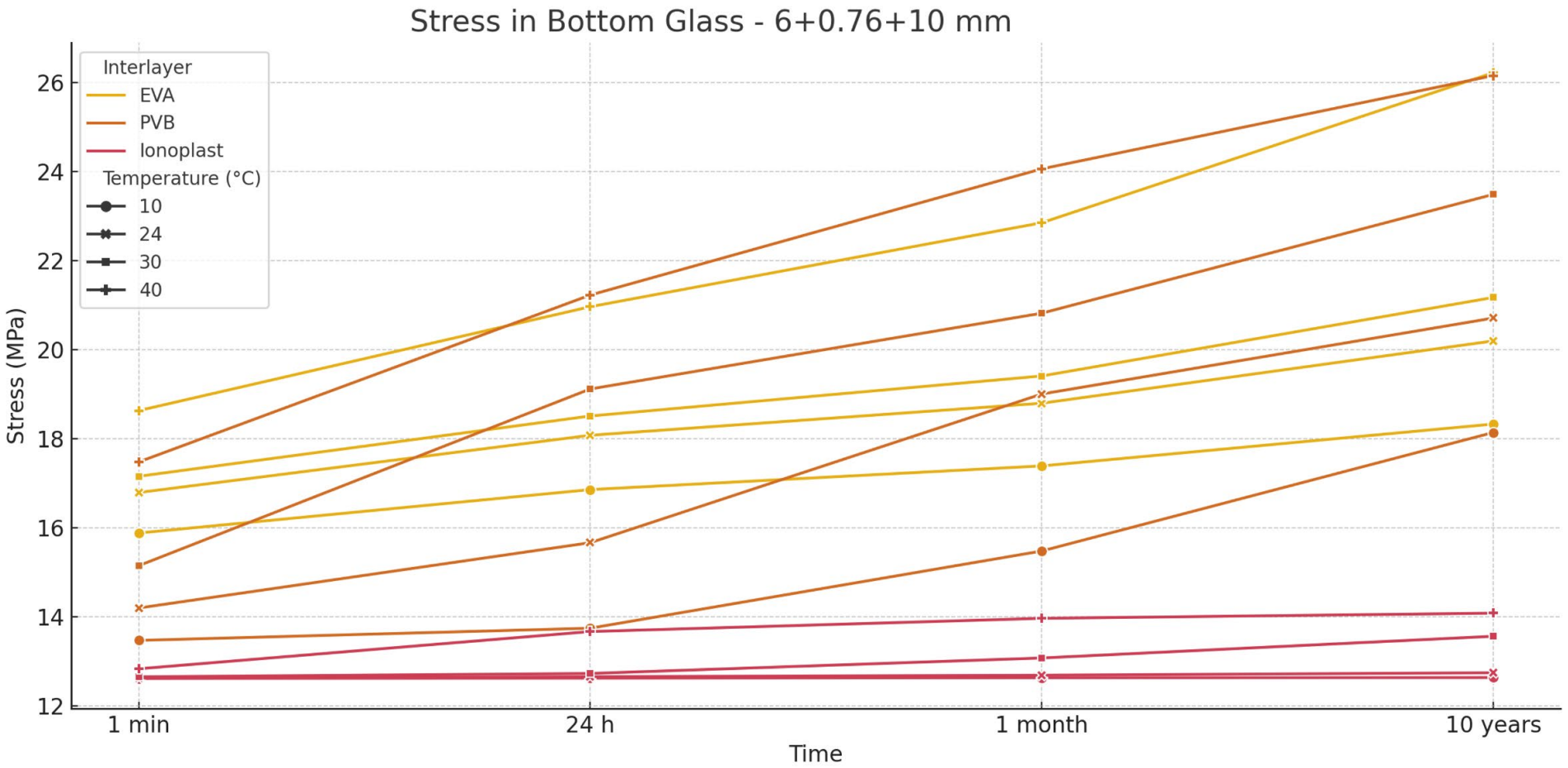
- Ionoplast maintains the lowest deflection again, confirming high stiffness and minimal time-temperature sensitivity
- PVB shows progressive deflection growth, especially beyond 24 h at elevated temperatures
- EVA behaves in between, showing moderate sensitivity to time and temperature



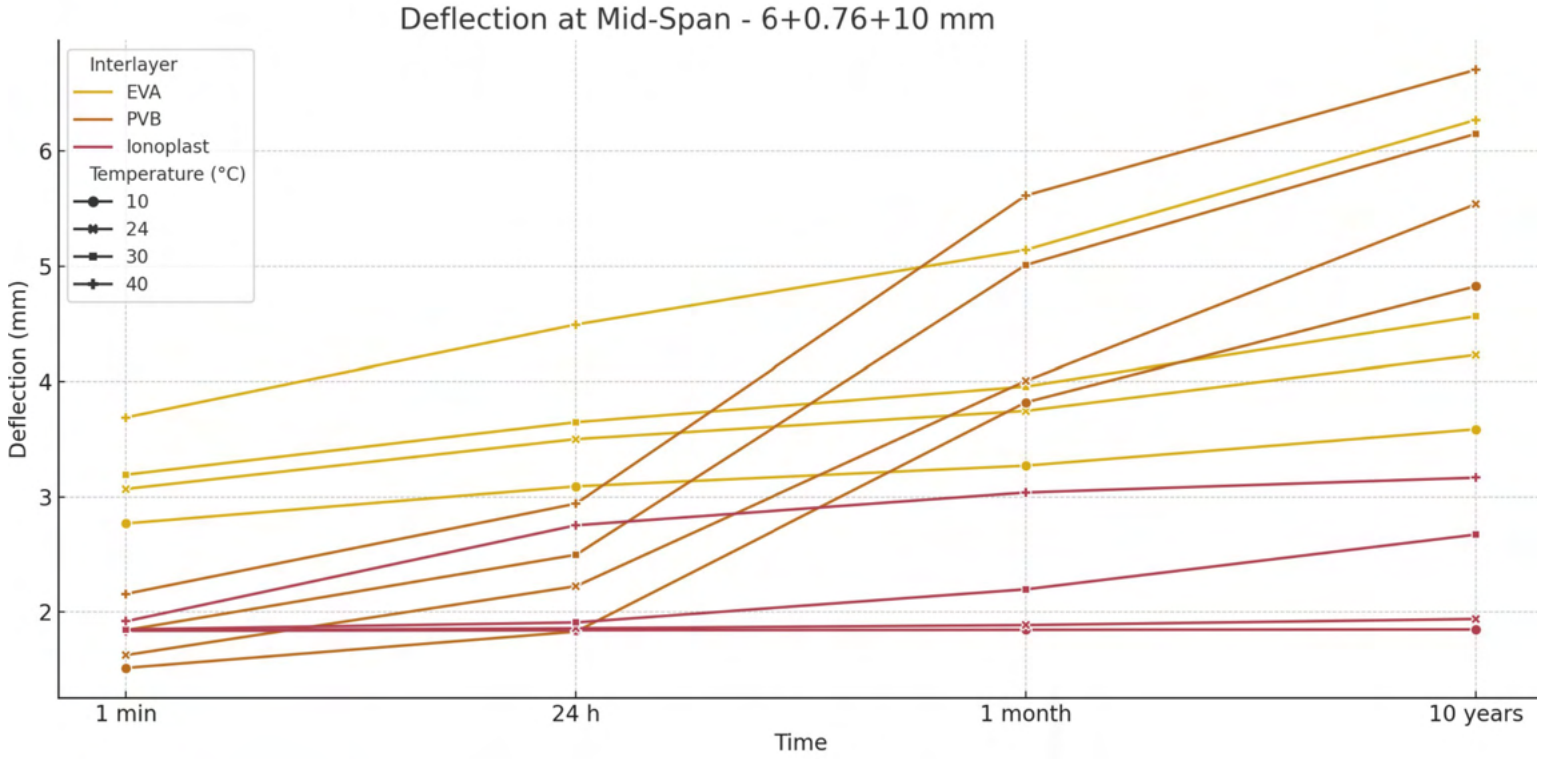
- EVA and PVB both exhibit rising stress over time, indicating a load shift from the softening interlayer to the glass
- Ionoplast handles load much more evenly, maintaining consistent stress in the bottom glass



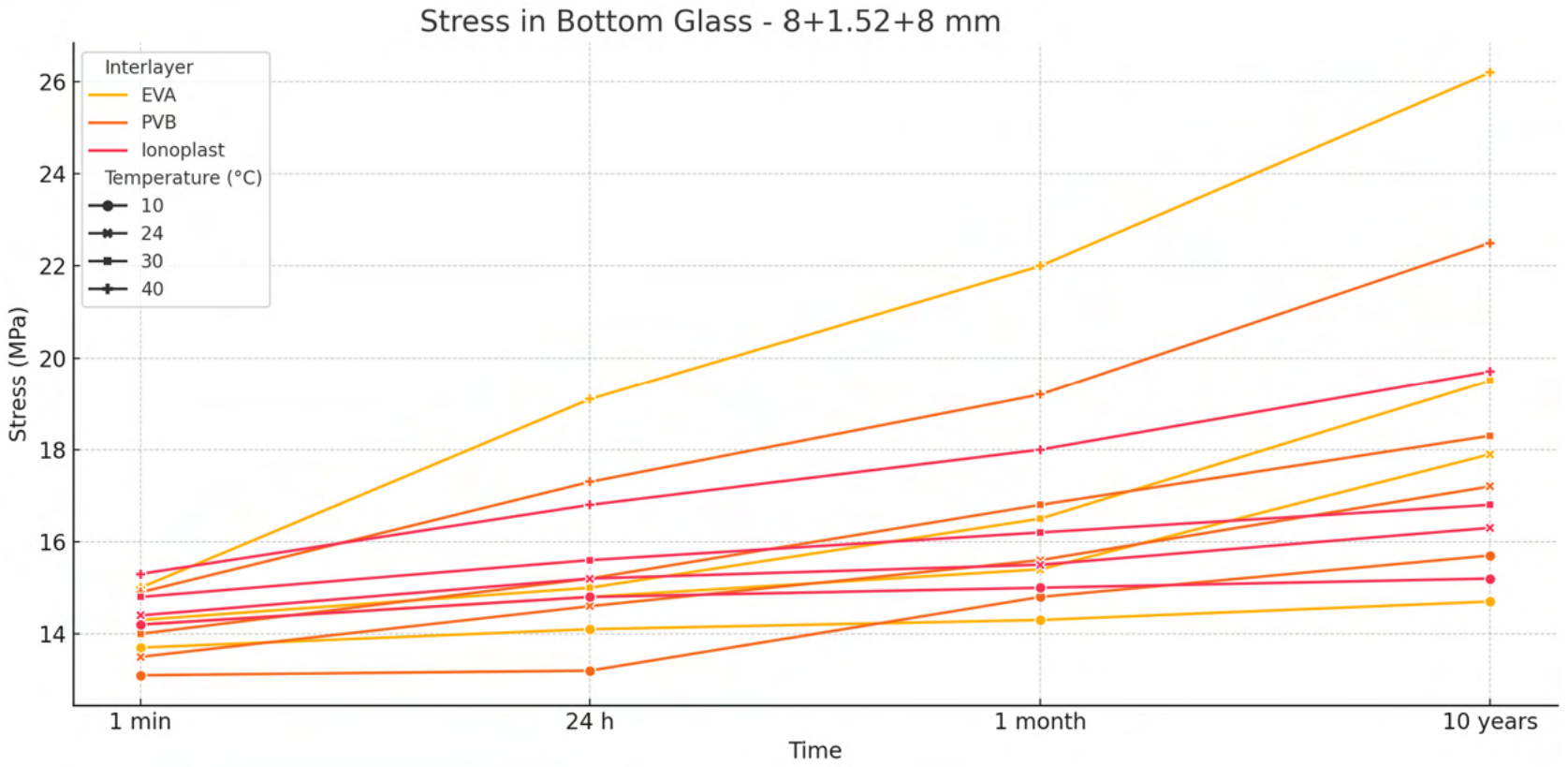
- Ionoplast shoes the lowest and most stable deflection, even at long durations and elevated temperatures
- PVB sees the greatest deflection creep, especially beyond 24 h and 30–40 °C
- EVA falls between the two in performance — softer than Ionoplast, but more stable than PVB



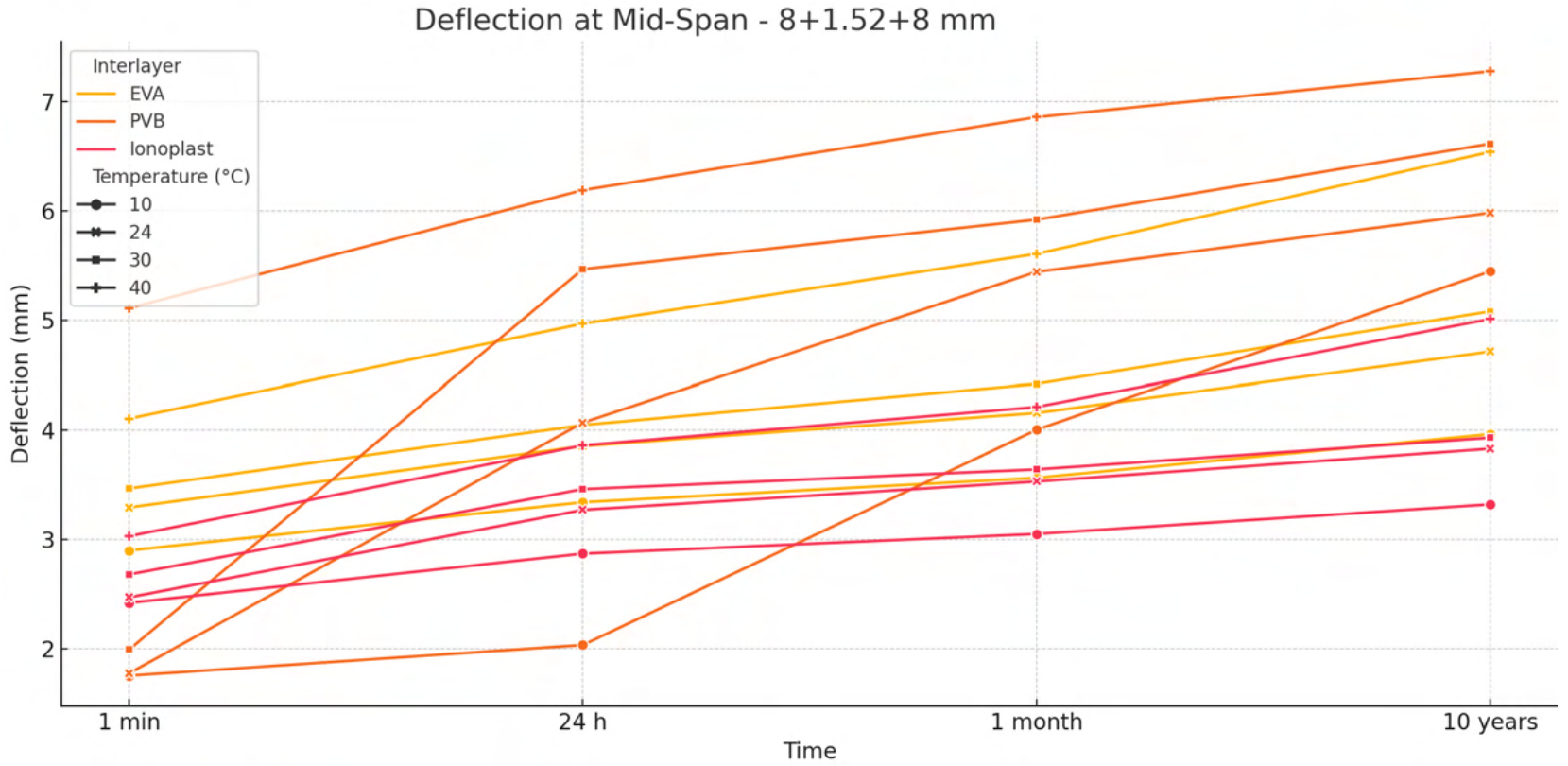
- EVA and PVB show significant stress increases with time and heat
- Ionoplast has constant stress, indicating good load-sharing capacity of the interlayer over long durations



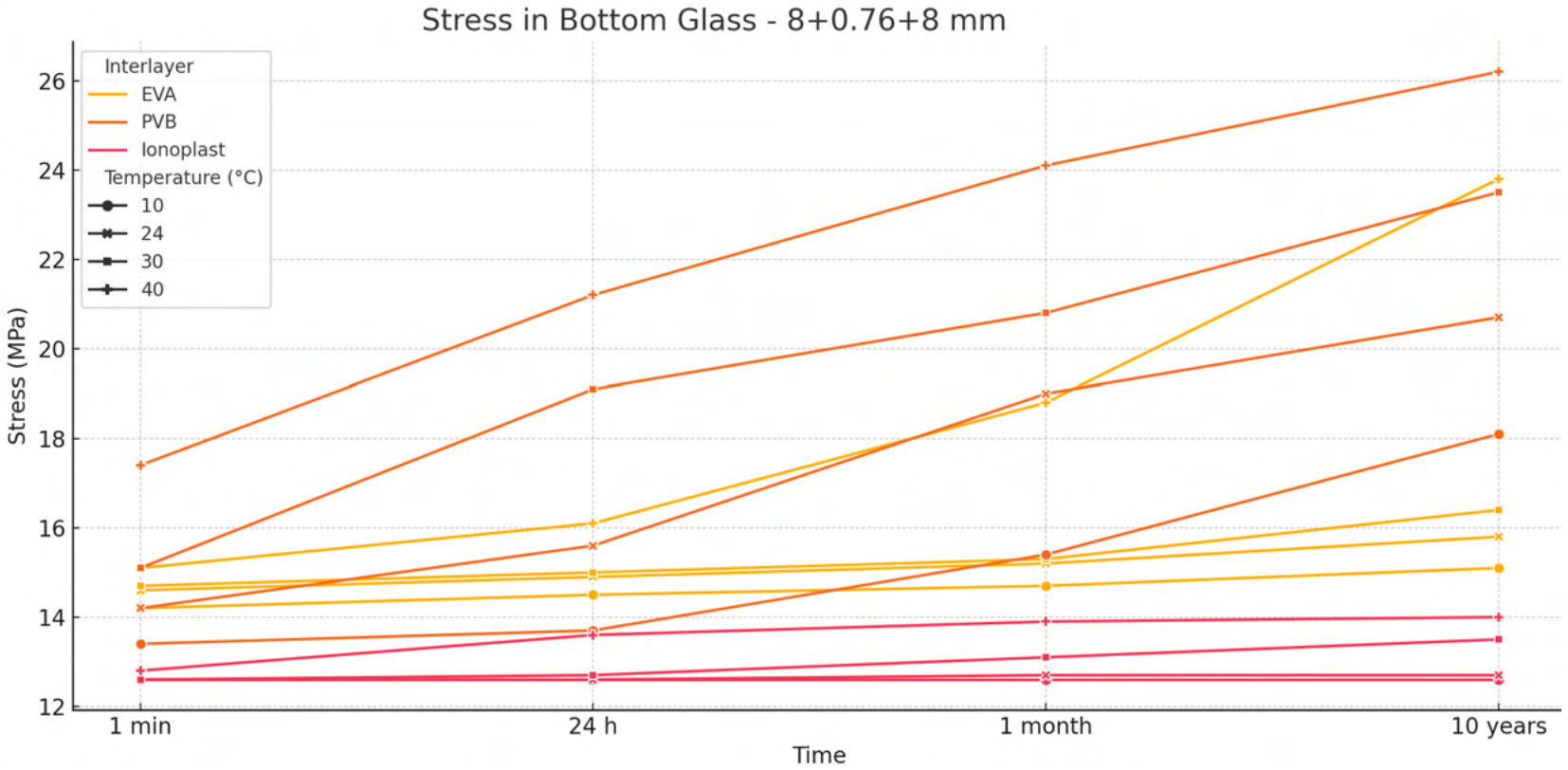
- Ionoplast again shows excellent stiffness — minimal increase in deflection even at 40 °C and 10 years
- PVB exhibits the highest deflection creep over time and temperature
- EVA performs moderately, with clearer separation from Ionoplast at elevated conditions



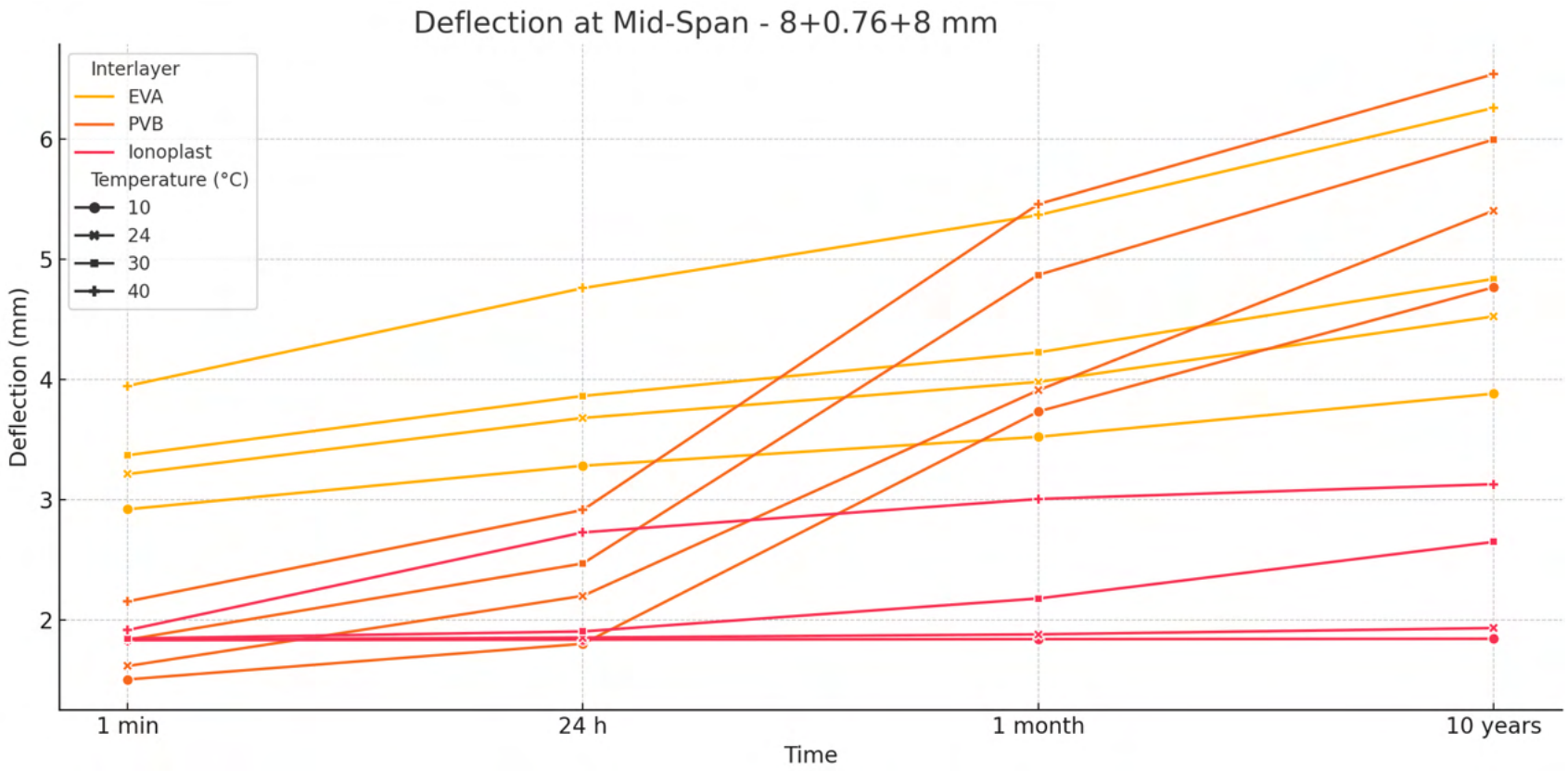
- Ionoplast keeps stress low
- EVA and PVB transfer more stress to the glass over time due to softening of the interlayer



- Ionoplast again maintains high stiffness with minimal deflection increase even after 10 years
- PVB shows the highest deformation, especially at elevated temperatures
- EVA performs better than PVB but still shows increased creep with time and temperature



- Ionoplast continues to distribute stress efficiently, minimising transfer to the glass
- EVA and PVB allow increased stress buildup in the glass, especially at high temperatures and longer durations



- Ionoplast again performs best with minimal deflection, maintaining stiffness across all durations and temperatures
- PVB shows the most pronounced creep, especially after 1 month and at 40 °C
- EVA deflects more than Ionoplast but remains stiffer than PVB under long-term conditions

SUMMARY

	EVA	PVB	Ionopast
Short-term stiffness	moderate	poor	very good
Long-term stiffness	moderate	poor	very good
Thermal stability	moderate	poor	very good
Glass stress protection	moderate	poor	very good

Thank you for Your attention!

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