CLIMATIC LOADS 3E
DESIGN METHODOLOGY COMPARISON

In order to understand the differences between the methodologies, this document contains a worked example, assessed by the following methods;

- Design charts,
- Permissible stress,
- Limit state design.

GLAZING SPECIFICATION

The glazing specification and installation details are as follows;

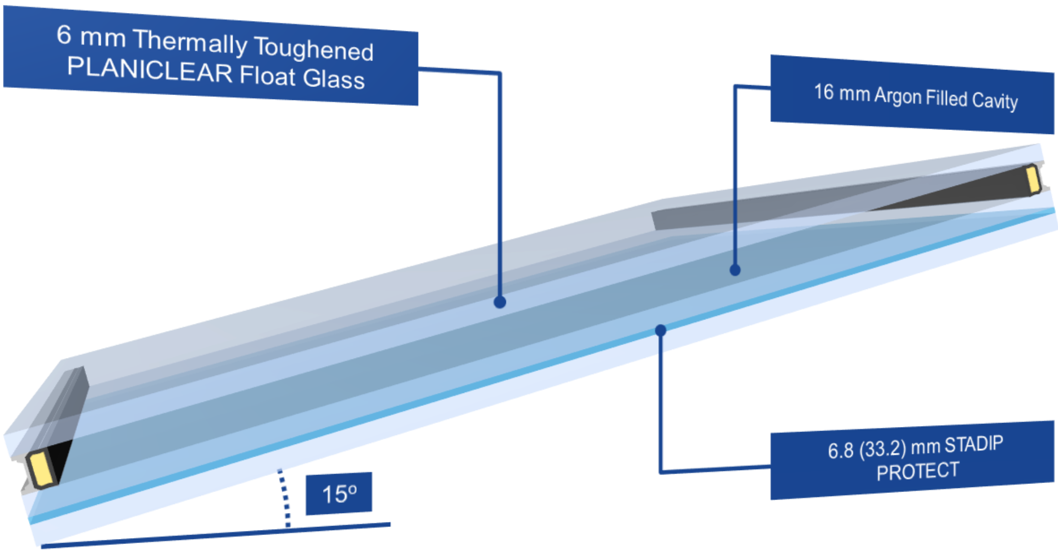


Table 1 - Worked Example Glazing Specification

Element	Thickness (mm)	Substrate
Outer Pane	6	Thermally Toughened
Cavity	16	Argon (90%)
Inner Pane	6.8 (33.2)	PVB Laminated Float Glass

Table 2 - Worked Example Load Conditions

Parameter	Value
Height (mm)	2500
Width (mm)	1200
Installation Angle (Degrees from Horizontal)	15
Characteristic Design Wind Load (Pressure) (kN/m^2)	1.2
Characteristic Design Wind Load (Suction) (kN/m^2)	1.5
Characteristic Design Snow Load (kN/m^2)	0.7
Edge Support (4 Edge, 2 Edge Vertical, 2 Edge Horizontal)	4

DESIGN CHARTS

The self-weight load, based on glass thickness, is as follows;

$$P_{SW} = (\rho \cdot t)\cos\alpha = [25000 \cdot (12 \times 10^{-3})]\cos 15 = 290\ Nm^{-2}$$

Based on the load combinations from BS 5516-2:2004 [1] provided, the following effective loads can be determined;

Table 3 - Worked Example Combined & Factored Loads

Scenario	Wind Pressure	Wind Suction	Snow	Self-Weight	Load
Stress, Downward Loads	720	---	1820	753	**3293**
	1200	---	1092	753	**3045**
Stress, Upward Loads	---	1500	---	290	**1790**
Deflection, Downward Loads	720	---	700	290	**1710**
	1200	---	420	290	**1910**
Deflection, Upward Loads	---	1500	---	290	**1790**

The effective area can be calculated, as per BS 5516-2, to give **2.63 m^2**. Coupled with the worst case load of **3293 N/m^2**, the following result could be taken from the design chart;

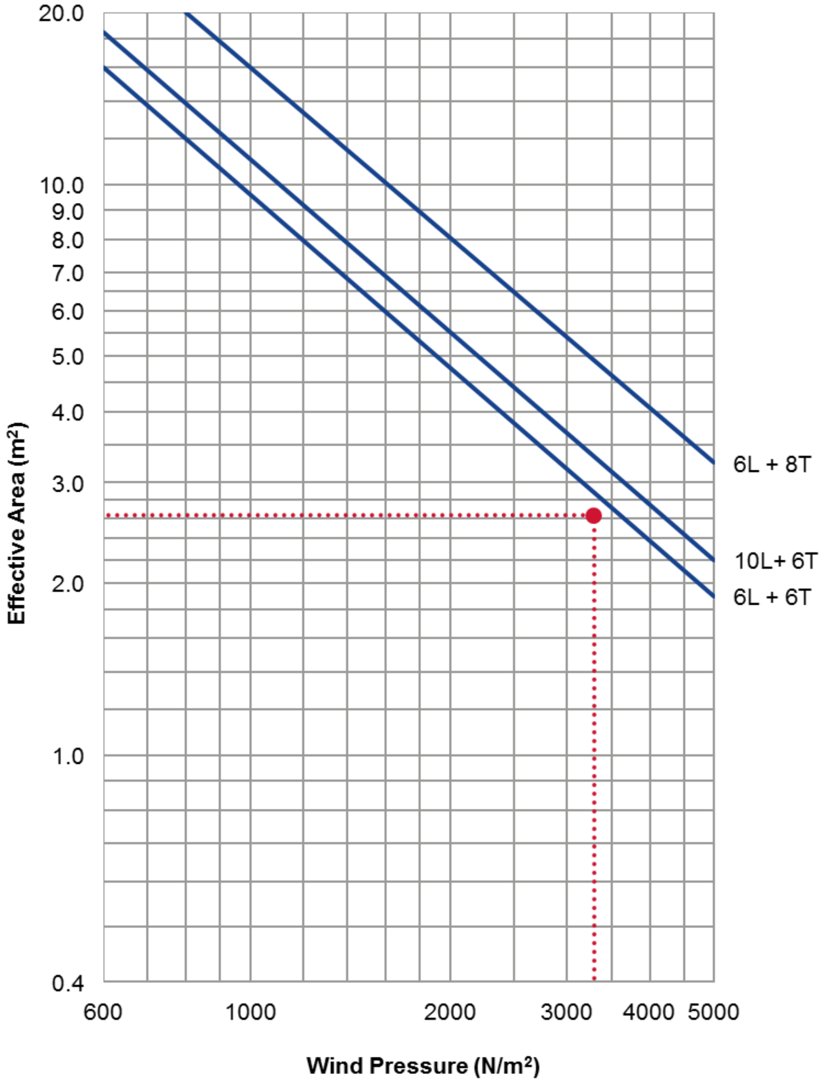
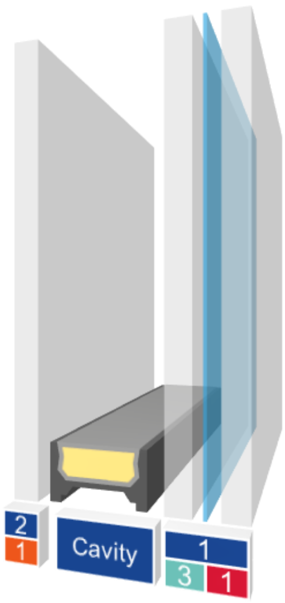


Figure 1 - Worked Example BS 5516-2 Design Chart Determination

Based on the chart, the glass is close to the permissible limit, however, no details are available from this method to determine if this is due to stress or deflection.

PERMISSIBLE STRESS DESIGN

Assessing the same pane using the BS 5516-2 load combinations, with vertical permissible stresses from TRLV [2], we get the following results from finite element analysis;



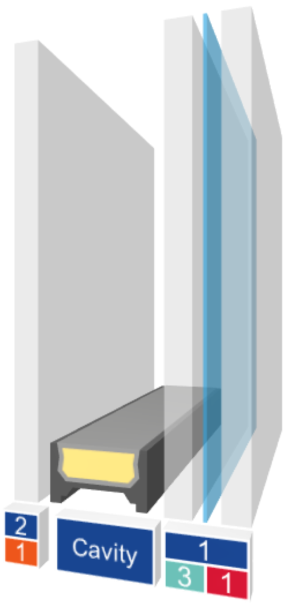
Package	Layer	Stress (N/mm²)		Deflection (mm)	
		Worst Case	Permissible	Worst Case	Permissible
2	1	32.36	50	16.23	38.46
Cavity					
1	3	18.31	22.5	15.26	38.46
	1	18.66	22.5		

Based on the result, deflection wouldn't be expected to be an issue, and the stress calculated is within the permissible limit, albeit close being within 20%.

LIMIT STATE DESIGN

As per **CLIMATIC LOADS 3D**, under limit state conditions [3, 4] both the loads and resistances will be factored. The following results are based on the information used for the previous two examples, with TRLV and DIN 18008 [2, 4] winter and summer climatic conditions also considered. In addition, shear within the interlayer is also considered.

The load case assessment results in 62 potential combinations for ultimate limit state, and 20 for serviceability limit state. The worst case results are shown below;



Package	Layer	Stress (N/mm²)		Deflection (mm)	
		Worst Case	Limit State	Worst Case	Serviceability State
2	1	31.30	80.00	16.99	38.46
Cavity					
1	3	22.25	31.50	17.00	38.46
	1	18.41	18.00		

The failure occurs for one specific load case, which is a combination as below, which is inclusive of interlayer shear effects;

Table 4 - Load Case of Failure

Scenario	Self-Weight	Snow	Wind Pressure	ΔH	ΔPΔT
Stress, Downward Loads	1.35	1.50	---	1.35	0.90

Under these conditions, the resistance to action for the glass types would be as below;

Package 1 (Annealed Laminate):

$$R_{d;A} = \frac{k_{mod} \cdot k_c \cdot f_{g;k}}{\gamma_{M;A}} \cdot f_{vsg} \cdot f_e$$

$$R_{d;A} = \frac{0.4 \times 1.8 \times 45}{1.8} \times 1.0 \times 1.0 = 18.00\ Nm^{-2}$$

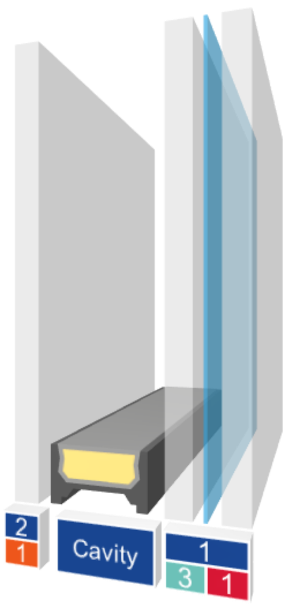
Package 2 (Pre-Stressed Glass):

$$R_{d;v} = \frac{f_{g;k}}{\gamma_{M;v}} \cdot f_{vsg}$$

$$R_{d;v} = \frac{120}{1.5} \cdot 1.0 = 80.00\ Nm^{-2}$$

Although this does fail, it is close to the limit (102.26%), and it should be remembered that in addition to the wind, snow and self-weight loads, climatic and altitude cavity loads are also considered.

As such, a more accurate assessment of climatic loadings might assist. For example, if the production to installation altitude was changed to **ΔH +50 m**, then the results change as below;



Package	Layer	Stress (N/mm^2)		Deflection (mm)	
		Worst Case	Limit State	Worst Case	Serviceability State
2	**1**	**30.72**	80.00	**16.62**	38.46
Cavity					
1	**3**	**21.11**	31.50	**15.90**	38.46
	1	**16.55**	18.00		

COMPARISON

If we consider the innermost ply of the glazing, under worst case conditions, we get the following comparative results;

Table 5 - Design Method Results Comparison

Method	Worst Case Load (N/m²)	Load Limit (N/m²)	% of Limit
Design Chart	3293	3616	91.06
Method	**Worst Case Stress (N/mm²)**	**Stress Limit (N/mm²)**	**% of Limit**
Permissible Stress	18.66	22.50	82.93
Limit State Design	16.55	18.00	91.94

In all 3 cases, the assessment indicates that the glass specification is suitable, and all are relatively close with regards the limit of allowable. However, to enable all potential loads to be considered, the limit state design methodology would typically be considered the most complete method.

With regards the accepted methodology, this will typically need to be one approved by Building Control, or other relevant certifying bodies.

REFERENCES

[1] British Standards Institute, *BS 5516-2:2004 - Patent glazing and sloping glazing for buildings. Code of practice for sloping glazing,* BSI, 2004.

[2] Deutsches Institut für Bautechnik, *Technische Regeln für die Verwendung von linienförmig gelagerten Verglasungen (TRLV),* DIBt, 2006.

[3] European Committee for Standardization, *EN 1990:2002 - Basis of structural design,* CEN, 2002.

[4] Deutsches Institut für Normung, *DIN 18008-1:2010-12 - Glas im Bauwesen - Bemessungs- und Konstruktionsregeln - Teil 1: Begriffe und allgemeine Grundlagen,* Beuth, 2012.