CLIMATIC LOADS 3C DESIGN METHODOLOGIES FOR OVERHEAD GLAZING

Designing glazing to withstand climatic loads is covered by various Codes of Practice and Standards. Three distinct methodologies exist, specifically;

- Design charts
- Permissible Stress
- Limit State Design (See **CLIMATIC LOADS 3D**)

With regards the accepted methodology, this will typically need to be one approved by Building Control, or other relevant certifying bodies. This document will introduce and discuss the various methods applicable to overhead glazing, which will typically be subjected to wind pressure, acting inwards to the building, wind suction, acting outwards from the building, downward snow loads, and self-weight.

DESIGN CHARTS

Within the UK, BS 5516-2:2004 [1] outlines both a method for determining the effect of combined wind, snow and self-weight loads for building as well as design charts for various glass substrate type combinations.

The design charts within BS 5516-2 are based on effective area and effective load. The effective area of the glazing (A_e) is determined based on the shape factor (F), and area (A) of the glazing. The shape factor is, in turn, determined from the aspect ratio (r) of the longest edge (a) to the shortest edge (b);

$$r = \frac{a}{b}$$

$$F = \frac{4 \cdot r}{(r+1)^2}$$

$$A_e = A \cdot F$$

The effective load is generated from the wind and snow loads, as determined by BS 6399-2 [2] and BS 6399-3 [3], or EN 1991-1-3 [4, 5] and EN 1991-1-4 [6, 7], with the following combinations.

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Table 1 - BS 5516-2 Load Case Combinations

Scenario	Wind Pressure	Wind Suction	Snow	Self-Weight
Stress, Downward Loads	0.6	---	2.6	2.6
	1.0	---	1.56	2.6
Stress, Upward Loads	---	1.0	---	1.0
Deflection, Downward Loads	0.6	---	1.0	1.0
	1.0	---	0.6	1.0
Deflection, Upward Loads	---	1.0	---	1.0

Whilst wind and snow loads are calculated from separate standards, the self-weight load (P_{SW}) will be determined based on the dimensions and thickness (t) of the glazing, the density ($\rho = 25000\ N/m^3$), and the angle (α) from horizontal, as follows;

$$P_{SW} = (\rho \cdot t) \cos \alpha$$

For example, a unit comprising two panes of 6 mm toughened float glass, installed at an angle of 20º from the horizontal would give the following load per square metre;

$$P_{SW} = (\rho \cdot t) \cos \alpha = [25000 \cdot (12 \times 10^{-3})] \cos 20 = 282\ Nm^{-2}$$

Once the wind, snow and self-weight loads are known, the load cases above can be assessed. Assuming the same unit as above, with a wind pressure of 1200 N/m^2, a wind suction of 1800 N/m^2 and a snow load of 650 N/m^2;

Table 2 - BS 5516-2 Example Combined & Factored Loads

Scenario	Wind Pressure	Wind Suction	Snow	Self-Weight	Load
Stress, Downward Loads	720	0	1690	733	**3143**
	1200	0	1014	733	**2947**
Stress, Upward Loads	0	1800	0	282	**2082**
Deflection, Downward Loads	720	0	650	282	**1652**
	1200	0	390	282	**1872**
Deflection, Upward Loads	0	1800	0	282	**2082**

If the unit measured 1000 mm x 2000 mm, this will give an effective area of 1.78 m^2. Using this value, in conjunction with the loads, will allow a specified thickness to be checked. The following chart, shows that a **6mm + 6mm** is sufficient based on the loads and dimensions. Adjusting self-weight to assess a **4mm + 4mm** construction, this is also sufficient.

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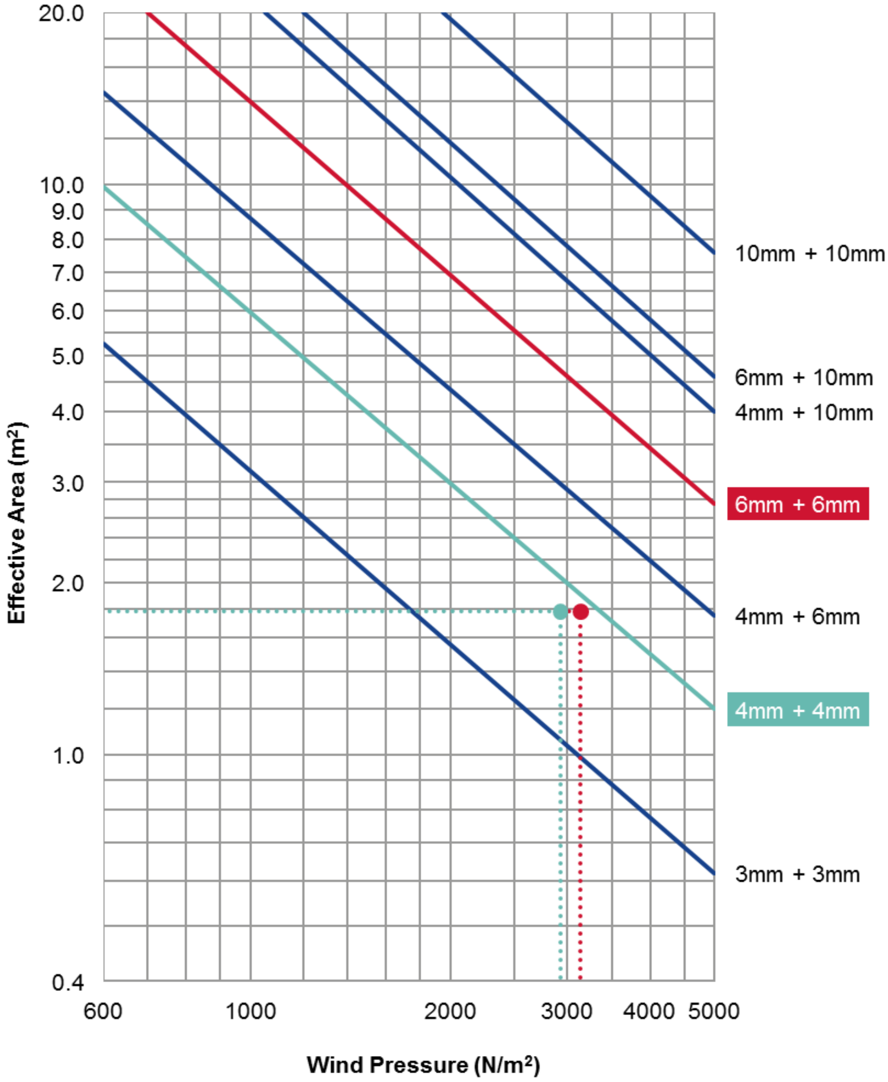

Figure 1 - Design Chart Example (BS 5516-2)

The above chart is intended for illustration only and should not be used to determine glass configurations to withstand wind, snow and self-weight loads. Instead, if applying this methodology, refer to the charts within BS 5516-2.

PERMISSIBLE STRESS DESIGN

Permissible stress design is a relatively simplistic method for determining the expected suitability of glass and glazing subjected to imposed loads. This method will permit any glazing configuration to be assessed, which exceeds the limited configurations provided within the BS 5516-2 design charts.

Under permissible stress design, loads provided for wind (BS 6262-3, BS 6399-2 [2] and/or BS EN 1991-1-4 [6, 7]), snow (BS 6399-3 [8] and/or BS EN 1991-1-3 [4, 5]), as well as self-weight, would be used as characteristic loads and applied, as factored in BS 5516-2, when determining stress and deflection generated.

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ALLOWABLE STRESS

Detail on the mechanical properties, failure modes and theoretical strength of glass is provided in a separate document. To simplify the determination of the ability of glass to withstand applied loads, the allowable stresses for glass are predominantly dependent upon the type of glass and the duration of a load, and factored as such.

BS 5516-2 provides no guidance on glass strength, as such alternative sources, such as German TRLV [9] guidelines can be considered.

TRLV GUIDANCE

German guidelines TRLV (Technical Rules for the Use of Line Bedded Glazing) [9] provides the following allowable stress limits;

Table 3 - TRLV Permissible Stresses

Glass Type	Permissible Stress (N/mm^2)	
	Vertical Glazing	Overhead Glazing
Thermally Toughened Float Glass	50	50
Thermally Toughened Patterned Glass	37	37
Enamelled Thermally Toughened Float Glass*	30	30
Heat Strengthened Glass	29	29
Enamelled Heat Strengthened Glass*	18	18
Annealed Float Glass	18	12
Annealed Patterned Glass	10	8
Laminated Annealed Float Glass	22.5	15 (25**)

* Permissible stress of enamelled surface.

** Allowable stress of lower laminated pane within an IGU in the even the upper pane has failed.

It should be noted that the TRLV guidelines are based on loads factored in a different manner to BS 5516-2, without adjustment for the influence of load duration on glass strength. As such, although permissible stress for overhead glazing may seem the more relevant value, with loads already factored, vertical glazing values may be accepted.

STRUCTURAL USE OF GLASS

Additional recommendations for allowable stresses are provided in Structural Use of Glass [10], which defines values based on load type and glass type;

Table 4 - IStructE Permissible Stresses

Load Type	Load Example	Glass Type Allowable Stress (N/mm^2)	
		Annealed	Thermally Toughened
Short Term Body Stress	Wind	28*	59
Short Term Edge Stress	Wind	17.8*	59
Medium Term	Snow	10.75	22.7
Medium Term	Floors	8.4	35
Long Term	Self-Weight, Water, Shelves	7	35

* Valid for annealed glass greater than 10 mm nominal thickness. For 6 mm nominal thickness glass, values may be multiplied by 1.4.

However, this potentially isn't suitable for load combinations.

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LIMIT STATE DESIGN

Limit state design is discussed in **CLIMATIC LOADS 3D**, as the methodology is complex and applicable to both vertical and overhead glazing.

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] British Standards Institute, *BS 6399-2:1997 - Loading for buildings. Code of practice for wind loads,* BSI, 1997.

[3] British Standards Institute, *BS 6262-3:2005 - Glazing for buildings. Code of practice for fire, security and wind loading,* BSI, 2005.

[4] European Committee for Standardization, *EN 1991-1-3:2003+A1:2015 - Eurocode 1. Actions on structures. General actions. Snow loads,* CEN, 2003/2015.

[5] European Committee for Standardization, *NA to BS EN 1991-1-3:2003 - UK National Annex to Eurocode 1. Actions on structures. General actions. Snow loads,* CEN, 2003.

[6] European Committee for Standardization, *EN 1991-1-4:2005+A1:2010 - Eurocode 1. Actions on structures. General actions. Wind actions,* CEN, 2005/2010.

[7] European Committee for Standardization, *NA to BS EN 1991-1-4:2005+A1:2010 - UK National Annex to Eurocode 1. Actions on structures. General actions. Wind actions,* CEN, 2005/2010.

[8] British Standards Institute, *BS 6399-3:1988 - Loading for buildings. Code of practice for imposed roof loads,* BSI, 1988.

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

[10] M. Haldimann, A. Luible and M. Overend, *Structural Use of Glass,* IABSE, 2008.

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