STRUCTURAL ASSESSMENT OF LAMINATED TOUGHENED GLASS
AS AN ALTERNATIVE TO 10MM MONOLITHIC TOUGHENED GLASS

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Introduction:

This assessment evaluates the structural suitability of laminated toughened glass panels as an alternative to 10 mm monolithic toughened glass. The analysis considers the effective thickness of the laminated glass in accordance with recognised engineering principles for laminated glazing, together with verification of bending strength and serviceability deflection under the specified design loading.

The following laminated glass configurations have been assessed:

- **Case A:** 5 mm Toughened Glass + 1.52 mm PVB Interlayer + 5 mm Toughened Glass
- **Case B:** 5 mm Toughened Glass + 0.76 mm PVB Interlayer + 5 mm Toughened Glass

Case A: 2 x 5mm with 1.5mm PVB interlayer:

Effective thickness of glass in terms of variable action where:

hef;w = $\sqrt[3]{\Sigma h_k^3 + 12\dot{\omega} (\Sigma h_k h_{m;k}^2)}$ {equation C.3}

$\dot{\omega}$ = coefficient of shear transfer of the interlayer
= 0.3 for standard grade PVB: family 2: for non-Mediterranean locations.

h_k = thickness of plies
= 5mm

hm;k = distance from mid-plane of glass plies to the centre of the PVB interlayer
= 3.25mm

hef;w = $\sqrt[3]{[(5)^3 + (5)^3 + 12 \times 0.3 (5 \times 3.25^2 + 5 \times 3.25^2)}$
= $\sqrt[3]{[125 + 125 + 3.6 (105.625)}$
= $\sqrt[3]{(630.25)}$

= 8.57mm

This is the effective thickness to be used for deflection calculations.

The effective thickness for bending stress $h_{ef;\alpha;j}$ = $\left\{ \dfrac{(h_{ef;w})^3}{h_j + 2\dot{\omega} h_{m;j}} \right\}^{0.5}$

= $\left\{ \dfrac{(8.57)^3}{5 + 2 \times 0.3 \times 3.25} \right\}^{0.5}$

= 9.54mm

This is the effective thickness to be used for bending stress calculations.

1st moment of area of glass based upon an effective thickness of 8.57mm and a nominal length of 1000mm = $\dfrac{1000 \times (9.54)^2}{6}$
= 15169mm^3

Moment capacity of glass = 87.53 N/mm^2 x 15169 x (10)$^{-6}$
= 1.328 kNm

Ultimate BM on glass spanning 1.0m and load of 1.50 kN/m^2 = $\dfrac{1.50 \times 1.0^2}{8}$
= 0.1875 kNm/m < 1.328 kNm/m OK

2^{nd} moment of area based upon an effective thickness of 8.57mm		=	$\frac{1000 \times (8.57)^3}{12}$
		=	$52452mm^4$
Service load deflection on a span of 1.0m simply supported		=	5 x (1000 x 1.0) (1000)3 384 x 70000 x 52452
		=	3.55mm < $\frac{span}{65}$ = OK
Moment capacity of laminated glass		=	1.328 kNm
Moment capacity of 10mm toughened glass		=	1.459 kN/m

The laminated glass has a slightly lower moment capacity than the 10mm single ply glass, however the laminated glass is adequate to resist the design loads in terms of both moment capacity and deflection limitations.

Case B: 2 x 5mm with 0.76mm PVB interlayer:

Effective thickness of glass in terms of variable action	hef;w	=	$^3\sqrt{} \Sigma h_k^3 + 12\dot{\omega} (\Sigma h_k \{h_{mk}\}2)$
where:	$\dot{\omega}$	=	coefficient of shear transfer of the interlayer
		=	0.3 for standard grade PVB: family 2: for non-Mediterranean locations.
	h_k	=	thickness of plies
		=	5mm
	$h_{m;k}$	=	distance from mid-plane of glass plies to the centre of the PVB interlayer
		=	2.88mm
	$h_{ef;w}$	=	$^3\sqrt{} [(5)^3 + (5)^3 + 12 \times 0.3 (5 \times 2.88^3 + 5 \times 2.88^3)$
		=	$^3\sqrt{} [125 + 125 + 3.6 (47.78)]$
		=	$^3\sqrt{} (422)$
		=	7.5mm

This is the effective thickness to be used for deflection calculations.

Effective thickness for bending stress	$h_{ef;\alpha;j}$	=	$\left\{ \frac{(h_{ef;w})^3}{h_k + 2 \times 0.3 \times 2.88} \right\}^{0.5}$
		=	$\left\{ \frac{(7.5)^3}{5 + 2 \times 0.3 \times 2.88} \right\}^{0.5}$
		=	7.92mm

This is the effective stress used for bending stress calculations.

1^{st} moment of area of glass based upon an effective thickness of 7.92mm		=	$\frac{1000 \times (7.92)^2}{6}$
and a nominal length of 1000mm		=	$10454mm^3$
Moment capacity of glass		=	$87.53 N/mm^2 \times 10454 \times (10)^{-6}$
		=	0.915 kNm/m
Ultimate BM on glass spanning 1.0m with load of 1.5 kN/m^2		=	$\frac{1.50 \times 1.02}{8}$
		=	0.1875 kNm/m < 0.915 kNm/m OK
2^{nd} moment of area based upon an effective thickness of 7.5mm		=	$\frac{1000 \times (7.5)^3}{12}$

	=	$35156mm^4$			
Service load deflection on a span of 1.0m simply supported	=	$\frac{5\ (1000 \times 1.0)\ (1000)3}{384 \times 70000 \times 35156}$			
	=	5.29mm <	$\frac{span}{65}$	=	OK
Moment capacity of laminated glass	=	0.915 kNm/m			
Moment capacity of 10mm glass	=	1.459 kNm/m			

The laminated glass has a lower moment capacity than 10mm single thickness toughened glass, however the laminated glass is adequate to resist the design load in terms of both moment capacity and deflection limitations.

Overall Conclusion:

The assessments demonstrate that both laminated glass configurations: **10.76 mm Laminated** Toughened Glass (5 mm + 0.76 mm PVB + 5 mm); and **11.52 mm Laminated** Toughened Glass (5 mm + 1.52 mm PVB + 5 mm) satisfy the requirements for bending resistance and serviceability deflection under the specified design loading conditions.

It is therefore concluded that both laminated glass constructions are structurally adequate for the loading conditions considered in this assessment and may be used as suitable alternatives to 10 mm monolithic toughened glass.

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