glassRAILINGS > PLAN
STRUCTURAL TESTING DATA

Structural Design
of
Glass Guardrail
for
GlassRAILING > PLAN

Prepared For

CARVART Glass
1441 Broadway 28th Floor
New York, NY 10018

Prepared By

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Job Description

This worksheet is for the stress/deflection summary table of the guardrail glass panel with varied width,height and thickness for Carvart Glass product. (highlighted in green is the recommendation, see next pages)

Notes

1. laminated full tempered glass guardrail with varied thickness and height are checked stress and deflection with different type of interlayer material (SGP and PVB).
2. only interior guardrail glass panel is checked with 50 pounds force pier linear foot or minimum 200 pounds force live load is applied at top of glass panel per NYC building code 2014 Edition.
3. effective thickness method for laminated glass panel is used per ASTM E1300-16 considering the load duration time and temperature.
4. maximum 6 ksi allowable tension stress in glass panel is used per NYC building code 2014 edition chapter 24.
5. no direct code requirement on the glass guardrail deflection check under live load, based on engineering judgement, one (1) inch deflection is set as the limit of deflection. note that the deflection limit may varies per specific project specification. so the calculated deflection is listed for reference purpose,
6. for stress and deflection check, cantilever length with fix support at finished floor is used.
7. structural silicone stress is checked.
8. with this report with glass shoe strength test report, which is provided by the third party.
9. concrete anchor design is provided as a sample, not direct design for specific project, contractor engineer of project shall be responsible for final anchor/screw design.

Project: **Carvart Interior Glass Guardrail Design**
Subject: **Summary Table of Guardrail Design**
Designed by:J. W
Date: 02/15/2021

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Table 1: Live load Stress/Deflection of laminated 43" high glass guardrail

43" high Guardrail free standing panel width (ft)	4 ft (min.)		3 ft		2ft	
Laminated Glass thickness	LL Glass Stress (ksi) *	LL Glass deflection (inches)**	LL Glass Stress (ksi)	LL Glass deflection (inches)	LL Glass Stress (ksi)	LL Glass deflection (inches)
1/4" FT + 0.06" SGP interlayer + 1/4" FT (total thickness: 9/16")	4.50	1.16	-	-	-	-
1/4" FT + 0.06" PVB interlayer + 1/4" FT (total thickness: 9/16")	-	-	-	-	-	-
5/16" FT + 0.06" SGP interlayer + 5/16" FT (total thickness: 11/16")	2.65	0.52	3.58	0.71	5.58	1.19
5/16" FT + 0.06" PVB interlayer + 5/16" FT (total thickness: 11/16")	4.79	1.73	-	-	-	-
3/8" FT + 0.06" SGP interlayer + 3/8" FT (total thickness: 13/16")	1.85	0.30	2.48	0.40	3.69	0.59
3/8" FT + 0.06" PVB interlayer + 3/8" FT (total thickness: 13/16")	3.41	1.04	4.80	1.50	-	-
1/2" FT + 0.06" SGP interlayer + 1/2" FT (total thickness: 17/16")	1.09	0.13	1.46	0.18	2.32	0.32
1/2" FT + 0.06" PVB interlayer + 1/2" FT (total thickness: 17/16")	2.07	0.49	2.88	0.69	4.62	1.15

Table 2: Live load Stress/Deflection of laminated 55" high glass guardrail

55" high Guardrail free standing panel width (ft)	4 ft (min.)		3 ft		2ft	
Laminated Glass thickness	LL Glass Stress (ksi) *	LL Glass deflection (inches)**	LL Glass Stress (ksi)	LL Glass deflection (inches)	LL Glass Stress (ksi)	LL Glass deflection (inches)
1/4" FT + 0.06" SGP interlayer + 1/4" FT (total thickness: 9/16")	5.7	2.37	-	-	-	-
1/4" FT + 0.06" PVB interlayer + 1/4" FT (total thickness: 9/16")	-	-	-	-	-	-
5/16" FT + 0.06" SGP interlayer + 5/16" FT (total thickness: 11/16")	3.37	1.06	4.57	1.48	-	-
5/16" FT + 0.06" PVB interlayer + 5/16" FT (total thickness: 11/16")	5.86	3.36	-	-	-	-
3/8" FT + 0.06" SGP interlayer + 3/8" FT (total thickness: 13/16")	2.35	0.61	3.17	0.84	4.89	1.37
3/8" FT + 0.06" PVB interlayer + 3/8" FT (total thickness: 13/16")	4.19	2.03	-	-	-	-
1/2" FT + 0.06" SGP interlayer + 1/2" FT (total thickness: 17/16")	1.39	0.28	1.87	0.38	2.96	0.66
1/2" FT + 0.06" PVB interlayer + 1/2" FT (total thickness: 17/16")	2.56	0.97	3.68	1.45	5.9	2.39

Table 3: Live Load Stress/Deflection of laminated 72" high glass guardrail

72" high Guardrail panel free standing width (ft)	4 ft (min.)		3 ft		2ft	
Laminated Glass thickness	LL Glass Stress (ksi) *	LL Glass deflection (inches)**	LL Glass Stress (ksi)	LL Glass deflection (inches)	LL Glass Stress (ksi)	LL Glass deflection (inches)
3/8" FT + 0.06" SGP interlayer + 3/8" FT (total thickness: 13/16")	3.06	1.36	4.13	1.87	-	-
3/8" FT + 0.06" PVB interlayer + 3/8" FT (total thickness: 13/16")	-	-	-	-	-	-
1/2" FT + 0.06" SGP interlayer + 1/2" FT (total thickness: 17/16")	1.81	0.61	2.44	0.83	3.86	1.46
1/2" FT + 0.06" PVB interlayer + 1/2" FT (total thickness: 17/16")	3.34	2.14	4.8	3.2	-	-

Notes

* max. allowable stress in full tempered glass is 6 ksi. Engineer's recommendation is highlighted in green color.
** No specific deflection limit per NYC Building Code 2014 edition. Maximum 1 inches is recommended based on engineer judgement.
*** stress/deflection is calculated under 50 plf or 200 lbf concentrated live load applied at top of guardrail, with load duration 24 hours.
**** effective thickness method is applied for laminated full tempered glass with SGP and PVB interlayer per ASTM E1300-16.

Recommended Concrete Anchor:

Recommended anchor for glassRAILING>PLAN: A. Side Mount:

1. 1/2" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 3.75" concrete embedment @ 12" max. spacing with minimum 2.5" concrete edge distance.
2. applicable to 43" high glass guardrail with minimum 4 ft wide.

Recommended anchor for glassRAILING>PLAN: B. Etended:

1. 3/8" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 2.5" concrete embedment @ 16" max. spacing with minimum 2.5" concrete edge distance.
2. applicable to 43" high glass guardrail with minimum 4 ft wide.

Appendix:

Stress/Deflection check & Silicone, Anchor design

Job Description

This worksheet is for the structural design of the 43" high glass guardrail with varied thickness for Carvart Glass product: glassRAILINGS > PLAN. the following items are Included:

1. Constants.
2. glass guardrail live load
3. 13/16" thick glass panel (4ft wide)
4. 11/16" thick glass panel (4ft wide)
5. 9/16" thick glass panel (4ft wide)
6. 17/16" thick glass panel (4ft wide)
7. 13/16" thick glass panel (3ft wide)
8. 11/16" thick glass panel (3ft wide)
9. 17/16" thick glass panel (3ft wide)
10. 9/16" thick glass panel (3ft wide)
11. 11/16" thick glass panel (2ft wide)
12. 13/16" thick glass panel (2ft wide)
13. 17/16" thick glass panel (2ft wide)

Design Notes and Results

1.) the scope of work: glass panel strength/deflection design,

2.) No strength check of existing structure or sybstrate or items by others are in the scope of work.

3.) work this design with glass railing product.

References

1.) AISC steel construction Manual. 15th Edition
2.) NYC building construction Code. 2014
3.) ACI 318-14 Chapter 17
4.) ASTM E1300-16: Standard Practice for Determining load Resistance of Glass in Buildings

Project: **Carvart Interior Glass Guardrail Design**
Subject: **43" high Guardrail (PLAN) Check**
Designed by:J. W
Date: 02/15/2021

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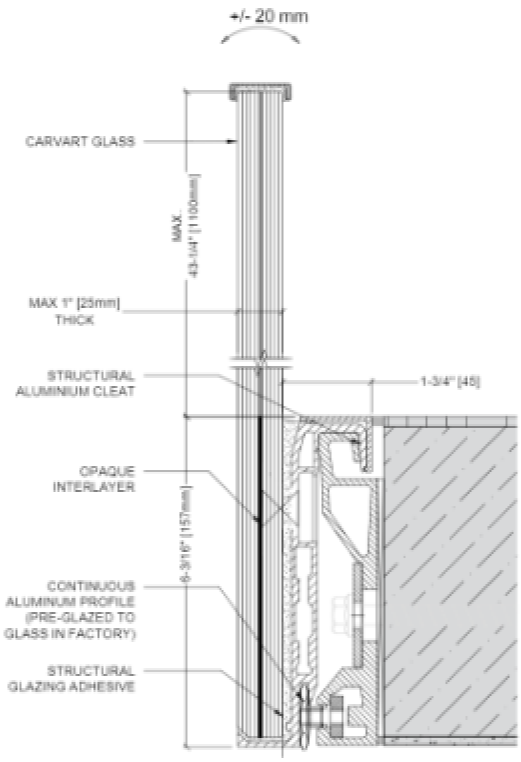
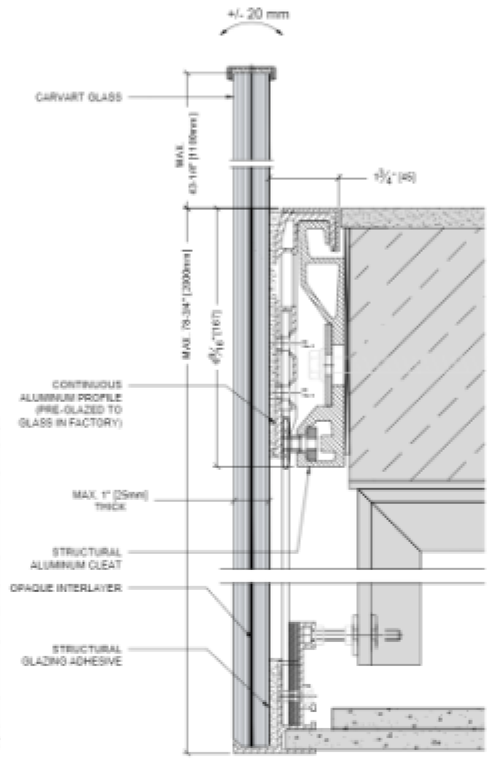


A. SIDE MOUNT



B. EXTENDED

1. Constants

$f_c := 2500psi$ — Design Compressive Strength of concrete (assumed)

$\gamma_{glass} := 160pcf$ — Density of glass

$\gamma_{stl} := 490pcf$ — Density of Steel

1.2 Dead Load (DC)

$Height_{glass} := 78in + \frac{3}{4}in + 43in + \frac{1}{4}in = 10.17\,ft$ — max. glass panel height

$Width_{glass} := 48in = 4.00\,ft$ — yypical glass panel width

$t_{glass\_max} := \frac{17}{16}in$ — max. Glass panel thickness (for dead load calculatin purpose)

$H_{guardrail} := 43in + \frac{1}{4}in = 3.60\,ft$ — height of glass guardrail (top of guardrail to finished floor)

Glass panel Dead Load:

$DL_{glasspanel} := 1.1\gamma_{glass} \cdot Height_{glass} \cdot t_{glass\_max} \cdot Width_{glass} = 633.72\,lbf$

2.1. Live Load (interior glass panel)

the following live load is applied on the interior glass guardrail:

guardrail railing: 50 plf in any direction applied on top of guardrail, or 200 lbf concentrated live load

$W_{panel\_design} := 48in = 4.00\,ft$ — design panel width for Live load

$V_{glass\_applied} := max\left(50plf \cdot W_{panel\_design}, 200lbf\right) = 200.00\,lbf$

$M_{glass\_applied} := V_{glass\_applied} \cdot \left(H_{guardrail}\right) = 8.65 \cdot kip \cdot in$ — max. bending moment at cener of structural silicone below the floor

2.2 lateral Load (applicable to glass panel, not for guardrail)

the following lateral load is applied on the infill of glass panel:

lateral load of 5 psf applied normal to the panels on the full extent of the solid vertical surface.

$UL_{lateral} := 5psf$ — lateral load on glass panel (not for guardrail)

3.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 4 ft

$h_1 := 0.355in$ — glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ — glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16}in = 0.06 \cdot in$ — interlayer thickness

$E_{glass} := 10399ksi$ — glass Young's modulus of elasticity

$G_{SGP\_wind} := 3828psi$ — interlayer complex shear modulus for 3S/122 F degree for SGP interlayer for wind load

$G_{SGP\_LL} := 8686psi$ — interlayer complex shear modulus for 1 hour /86 F degree for SGP interlayer for live load

$G_{PVB\_wind} := 63.8psi$ — interlayer complex shear modulus for 3S/122 F degree for PVB interlayer for wind load

$G_{PVB\_LL} := 63.9psi$ — interlayer complex shear modulus for 1 hour/86 F degree for PVB interlayer for live load

G value reference:
https://www.trosifol.com/glass-calculator/?no_cache=1&tx_glasscalculator_calculator%5Baction%5D=showCase1&tx_glasscalculator_calculator%5Bcontroller%5D=Start&cHash=0a59bd8a690a1465001bfbc556618a00

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^2 + h_2 \cdot h_{s1}^2 = 0.03 \cdot in^3$$

$$a := \min(Height_{glass}, Width_{glass}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^2 a^2} \right)} = 0.89$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^2 a^2} \right)} = 0.95$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.748 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{3}}{h_1 + 2\cdot\Gamma_{wind\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.760\cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{3} + h_2^{3} + 12\cdot\Gamma_{LL\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.761\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{3}}{h_1 + 2\cdot\Gamma_{LL\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.767\cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_wind}\cdot h_s^{2}\,a^{2}}\right)} = 0.12$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_LL}\cdot h_s^{2}\,a^{2}}\right)} = 0.12$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{3} + h_2^{3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.510\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.574\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{LL\_PVB} \cdot I_s\right)^{\frac{1}{3}} = 0.511 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2 \cdot \Gamma_{LL\_PVB} \cdot h_{s2}}\right)^{0.5} = 0.574 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

3.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$Fr := 24ksi$$

Average Modulus of Rupture for fully tempered glass

$$\sigma_{glass\_allowable} := \frac{Fr}{4} = 6.00 \cdot ksi$$

Typical glass allowable bending stress, where factor 4 is the Safety Factor

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12} \cdot W_{panel\_design} = 1.77 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6} \cdot W_{panel\_design} = 4.70 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 1.84 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} "OK !!" & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ "NG !!" & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = "OK !!"$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.53 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 2.63 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 3.28 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} "OK !!" & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ "NG !!" & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = "OK !!"$

3.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.29 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.29 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

3.2 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 0.97 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 0.97 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

4.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(5/16" FT + 0.06" Interlayer +5/16" FT) : total thickness: 11/16", Panel width: 4 ft

$h_{1\_1} := 0.292in$ glass minimum thickness of nominal 5/16" thick

$h_{2\_1} := 0.292in$ glass minimum thickness of nominal 5/16" thick

$h_{v\_1} := \frac{1}{16}in = 0.06\cdot in$ interlayer thickness

$h_{s\_1} := 0.5\cdot(h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.35\cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1}\cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.18\cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1}\cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.18\cdot in$$

$$I_{s\_1} := h_{1\_1}\cdot h_{s2\_1}^{\ 2} + h_{2\_1}\cdot h_{s1\_1}^{\ 2} = 0.02\cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 48.00\cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_{s\_1}\cdot h_{v\_1}}{G_{SGP\_wind}\cdot h_{s\_1}^{\ 2}\, a_1^{\ 2}}\right)} = 0.91$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^2 a_1^2} \right)} = 0.93$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^3 + h_{2\_1}^3 + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.629 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^3}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.638 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^3 + h_{2\_1}^3 + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.634 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^3}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.640 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^2 a_1^2} \right)} = 0.14$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^2 a_1^2} \right)} = 0.14$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.432\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}{}^3}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.485\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.432\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}{}^3}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.485\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

4.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}{}^3}{12}\cdot W_{panel\_design} = 1.02\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}{}^2}{6}\cdot W_{panel\_design} = 3.27\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 2.64 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.32 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 1.89 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 4.59 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"OK !!"}$

4.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.51 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.51 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

4.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 1.61 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 1.61 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

5.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(1/4" FT + 0.06" Interlayer +1/4" FT) : total thickness: 9/16" , Panel width: 4 ft

$h_{1\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{2\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.28 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.01 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.93$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} \, a_1^{2}} \right)} = 0.89$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.490 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.495 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.485 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.492 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} \, a_1^{2}} \right)} = 0.18$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} \, a_1^{2}} \right)} = 0.18$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.340 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.383 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.340 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.383 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

5.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{\ 3}}{12} \cdot W_{panel\_design} = 0.46 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{\ 2}}{6} \cdot W_{panel\_design} = 1.94 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 4.46 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{{h_{ef\_LL\_PVB\_1}}^3}{12} \cdot W_{panel\_design} = 0.16 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{{h_{1\_ef\_\sigma\_LL\_PVB\_1}}^2}{6} \cdot W_{panel\_design} = 1.17 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 7.37 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"NG !!"}$

5.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.14 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.14 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

5.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 3.29 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 3.29 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

6.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) : total thickness: 17/16" , Panel width: 4 ft

$h_{1\_1} := 0.469in$ — glass minimum thickness of nominal 1/2" thick

$h_{2\_1} := 0.469in$ — glass minimum thickness of nominal 1/2" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ — interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.53 \cdot in$ — ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.07 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.86$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.97$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.961 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.980 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.992 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.996 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.09$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.09$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}{}^{3} + h_{2\_1}{}^{3} + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.653\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}{}^{3}}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.734\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}{}^{3} + h_{2\_1}{}^{3} + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.653\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}{}^{3}}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.734\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

6.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}{}^{3}}{12}\cdot W_{panel\_design} = 3.90\cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}{}^{2}}{6}\cdot W_{panel\_design} = 7.94\cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 1.09 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 1.12 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 4.31 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 2.01 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"OK !!"}$

6.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.13 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.13 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

6.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 0.46 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 0.46 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

7.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_1 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^{\ 2} + h_2 \cdot h_{s1}^{\ 2} = 0.03 \cdot in^3$$

$$a := \min(Height_{glass}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^{\ 2}\, a^2} \right)} = 0.82$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^{\,2} a^2} \right)} = 0.91$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.732 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{\,3}}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.751 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.753 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{\,3}}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.763 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^{\,2} a^2} \right)} = 0.07$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^{\,2} a^2} \right)} = 0.07$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{wind\_PVB} \cdot I_s\right)^{\frac{1}{3}} = 0.487 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2 \cdot \Gamma_{wind\_PVB} \cdot h_{s2}}\right)^{0.5} = 0.548 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{LL\_PVB} \cdot I_s\right)^{\frac{1}{3}} = 0.487 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2 \cdot \Gamma_{LL\_PVB} \cdot h_{s2}}\right)^{0.5} = 0.548 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

7.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12} \cdot W_{panel\_design} = 1.28 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6} \cdot W_{panel\_design} = 3.49 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 2.48 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.35 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 1.80 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 4.80 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = \text{"OK !!"}$

7.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.30 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.40 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

7.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 1.12 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 1.50 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

8.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(5/16" FT + 0.06" Interlayer +5/16" FT) : total thickness: 11/16", Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.292in$ glass minimum thickness of nominal 5/16" thick

$h_{2\_1} := 0.292in$ glass minimum thickness of nominal 5/16" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.35 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.02 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2}\, a_1^{\ 2}} \right)} = 0.84$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.88$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.618 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.631 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.624 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.635 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.08$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} a_{1}^{2}} \right)} = 0.08$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.408 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.460 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.408 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.460 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

8.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12} \cdot W_{panel\_design} = 0.73 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{{h_{1\_ef\_\sigma\_LL\_1}}^2}{6} \cdot W_{panel\_design} = 2.42 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 3.58 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1}$ = "OK !!"

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{{h_{ef\_LL\_PVB\_1}}^3}{12} \cdot W_{panel\_design} = 0.20 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{{h_{1\_ef\_\sigma\_LL\_PVB\_1}}^2}{6} \cdot W_{panel\_design} = 1.27 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 6.80 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1}$ = "NG !!"

8.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.53 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.71 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

8.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 1.90 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 2.54 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

Project: **Carvart Interior Glass Guardrail Design**
Subject: **43" high Guardrail (PLAN) Check**
Designed by:J. W
Date: 02/15/2021

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9.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) : total thickness: 17/16" , Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{2\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.53 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\,2} + h_{2\_1} \cdot h_{s1\_1}^{\,2} = 0.07 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\,2} a_1^{\,2}}\right)} = 0.77$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.94$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.936 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.966 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.985 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.993 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.05$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.05$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.629 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.707 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.629 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.707 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

9.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12} \cdot W_{panel\_design} = 2.87 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{2}}{6} \cdot W_{panel\_design} = 5.91 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 1.46 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{\;3}}{12} \cdot W_{panel\_design} = 0.75 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{\;2}}{6} \cdot W_{panel\_design} = 3.00 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 2.88 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_PVB\_1} = \text{"Ok !!"}$$

9.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.14 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.18 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

9.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 0.52 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 0.69 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

10.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/4" FT + 0.06" Interlayer +1/4" FT) : total thickness: 9/16" , Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{2\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.28 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}{}^2 + h_{2\_1} \cdot h_{s1\_1}{}^2 = 0.01 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}{}^2 a_1{}^2} \right)} = 0.88$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.82$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.483 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.491 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.474 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.487 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.11$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.11$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.318 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.360 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.318 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.360 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

10.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12} \cdot W_{panel\_design} = 0.32 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{2}}{6} \cdot W_{panel\_design} = 1.42 \cdot in^3$

Section modulus of one glass panel for stress check under LL

$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 6.09 \cdot ksi$

Applied bending stress in glass under live load

$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$

$Check_{glass\_stress\_SGP\_1} = \text{"NG !!"}$

$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.10 \cdot in^4$

moment of inertia of glass panel for deflection check under LL (for PVB)

$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 0.78 \cdot in^3$

Section modulus of one glass panel for stress check under LL (for PVB)

$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 11.15 \cdot ksi$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_PVB\_1} = \text{"NG !!"}$$

10.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.22 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.62 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

10.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 4.02 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 5.36 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

11.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(5/16" FT + 0.06" Interlayer +5/16" FT) : total thickness: 11/16" , Panel width: 2 ft

$W_{panel\_design} := 24in = 2.00\,ft$

$h_{1\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{2\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ — interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.35 \cdot in$ — ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.02 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2} \, a_1^{\ 2}} \right)} = 0.71$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

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$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.77$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.590 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.615 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.602 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.622 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.04$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.04$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.388\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.437\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.388\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.437\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

11.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12}\cdot W_{panel\_design} = 0.44\cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{2}}{6}\cdot W_{panel\_design} = 1.55\cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 5.58 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.12 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 0.76 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 11.33 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"NG !!"}$

11.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.59 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.19 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

11.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 2.22 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 4.44 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

12.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 2 ft

$W_{panel\_design} := 24in = 2.00 ft$

$h_1 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16} in = 0.06 \cdot in$ interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^2 + h_2 \cdot h_{s1}^2 = 0.03 \cdot in^3$$

$$a := \min(Height_{glass}, W_{panel\_design}) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^2 a^2} \right)} = 0.67$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^2 \, a^2} \right)} = 0.82$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.696 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^3}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.729 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.733 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^3}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.751 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^2 \, a^2} \right)} = 0.03$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^2 \, a^2} \right)} = 0.03$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.466\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.525\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.466\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.525\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

12.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12}\cdot W_{panel\_design} = 0.79\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6}\cdot W_{panel\_design} = 2.26\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 3.83 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.20 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 1.10 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 7.86 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = \text{"NG !!"}$

12.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.33 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.66 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

12.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 1.28 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.56 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

13.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) total thickness: 17/16", Panel width: 2 ft

$W_{panel\_design} := 24 in = 2.00 ft$

$h_1 := 0.469 in$ glass minimum thickness of nominal 1/2" thick

$h_2 := 0.469 in$ glass minimum thickness of nominal 1/2" thick

$h_v := \frac{1}{16} in = 0.06 \cdot in$ interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.53 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.27 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.27 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^2 + h_2 \cdot h_{s1}^2 = 0.07 \cdot in^3$$

$$a := \min(Height_{glass}, W_{panel\_design}) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^2 a^2} \right)} = 0.60$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{SGP\_LL}\cdot h_s^{2}\, a^{2}}\right)} = 0.77$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^{3} + h_2^{3} + 12\cdot\Gamma_{wind\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.881\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{3}}{h_1 + 2\cdot\Gamma_{wind\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.932\cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{3} + h_2^{3} + 12\cdot\Gamma_{LL\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.937\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{3}}{h_1 + 2\cdot\Gamma_{LL\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.966\cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_wind}\cdot h_s^{2}\, a^{2}}\right)} = 0.02$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_LL}\cdot h_s^{2}\, a^{2}}\right)} = 0.02$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.609\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.684\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.609\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.684\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

13.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12}\cdot W_{panel\_design} = 1.64\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6}\cdot W_{panel\_design} = 3.73\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 2.32 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_SGP} = \text{"OK !!"}$$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{\,3}}{12} \cdot W_{panel\_design} = 0.45 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{\,2}}{6} \cdot W_{panel\_design} = 1.87 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 4.62 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_PVB} = \text{"OK !!"}$$

14.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.16 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.32 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

14.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 0.57 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 1.15 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

Job Description

This worksheet is for the structural design of the 55" high glass guardrail with varied thickness for Carvart Glass product: glassRAILINGS > LEVEL & UNI. the following items are Included:

Design Notes and Results

1.) the scope of work: glass panel strength/deflection design,

2.) No strength check of existing structure or sybstrate or items by others are in the scope of work.

3.) work this design with glass railing product.

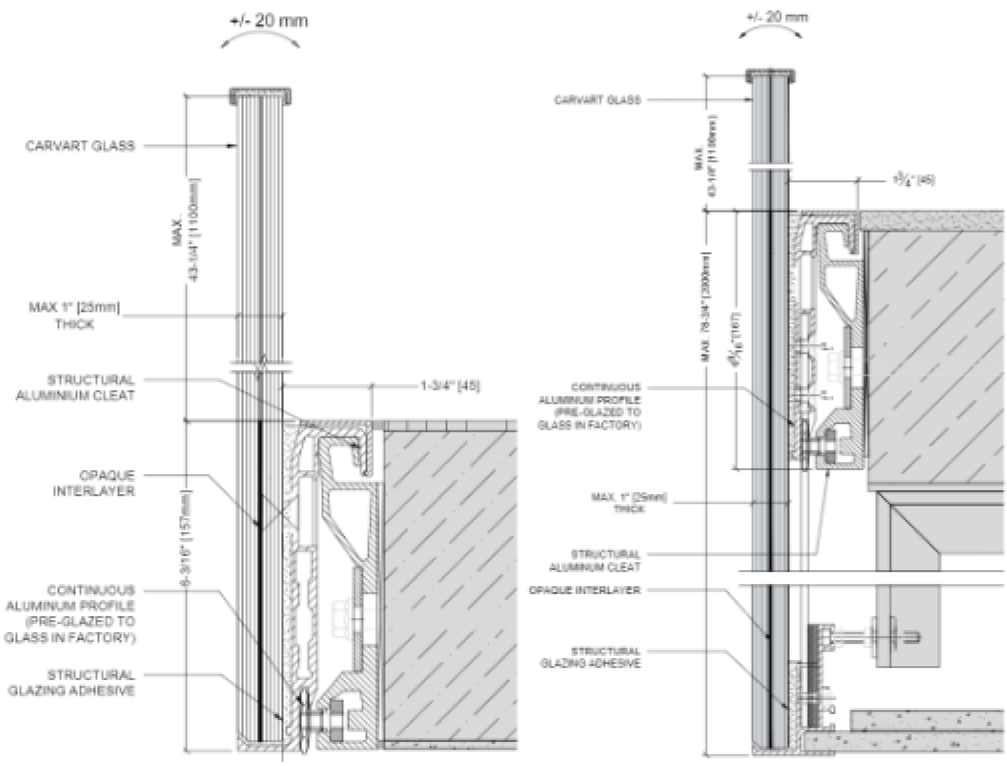
References

1.) AISC steel construction Manual. 15th Edition
2.) NYC building construction Code. 2014
3.) ACI 318-14 Chapter 17
4.) ASTM E1300-16: Standard Practice for Determining load Resistance of Glass in Buildings

Project: **Carvart Interior Glass Guardrail Design**
Subject: **55" high Guardrail (UNI & LEVEL) Check**
Designed by:J. W
Date: 02/15/2021

Index No. .
Job. No. .

glassRAILINGS>PLAN



A. SIDE MOUNT **B. EXTENDED**

1. Constants

$f_c := 2500psi$ — Design Compressive Strength of concrete (assumed)

$\gamma_{glass} := 160pcf$ — Density of glass

$\gamma_{stl} := 490pcf$ — Density of Steel

1.2 Dead Load (DC)

$Height_{glass} := 6in + \frac{5}{16}in + 55in + \frac{1}{8}in = 5.12\,ft$ — max. glass panel height

$Width_{glass} := 48in = 4.00\,ft$ — yypical glass panel width

$t_{glass\_max} := \frac{17}{16}in$ — max. Glass panel thickness (for dead load calculatin purpose)

$H_{guardrail} := 55in + \frac{1}{4}in = 4.60\,ft$ — height of glass guardrail (top of guardrail to finished floor)

Glass panel Dead Load:

$DL_{glasspanel} := 1.1\gamma_{glass} \cdot Height_{glass} \cdot t_{glass\_max} \cdot Width_{glass} = 319.13\,lbf$

2.1. Live Load (interior glass panel)

the following live load is applied on the interior glass guardrail:

guardrail railing: 50 plf in any direction applied on top of guardrail, or 200 lbf concentrated live load

$W_{panel\_design} := 48in = 4.00\,ft$

design panel width for Live load

$V_{glass\_applied} := \max\left(50plf \cdot W_{panel\_design}, 200lbf\right) = 200.00\,lbf$

$M_{glass\_applied} := V_{glass\_applied} \cdot \left(H_{guardrail}\right) = 11.05 \cdot kip \cdot in$

max. bending moment at cener of structural silicone below the floor

2.2 lateral Load (applicable to glass panel, not for guardrail)

the following lateral load is applied on the infill of glass panel:

lateral load of 5 psf applied normal to the panels on the full extent of the solid vertical surface.

$UL_{lateral} := 5psf$

lateral load on glass panel (not for guardrail)

3.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 4 ft

$h_1 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16} in = 0.06 \cdot in$ interlayer thickness

$E_{glass} := 10399ksi$ glass Young's modulus of elasticity

$G_{SGP\_wind} := 3828psi$ interlayer complex shear modulus for 3S/122 F degree for SGP interlayer for wind load

$G_{SGP\_LL} := 8686psi$ interlayer complex shear modulus for 1 hour /86 F degree for SGP interlayer for live load

$G_{PVB\_wind} := 63.8psi$ interlayer complex shear modulus for 3S/122 F degree for PVB interlayer for wind load

$G_{PVB\_LL} := 63.9psi$ interlayer complex shear modulus for 1 hour/86 F degree for PVB interlayer for live load

G value reference:
https://www.trosifol.com/glass-calculator/?no_cache=1&tx_glasscalculator_calculator%5Baction%5D=showCase1&tx_glasscalculator_calculator%5Bcontroller%5D=Start&cHash=0a59bd8a690a1465001bfbc556618a00

$$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$$

ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^{\ 2} + h_2 \cdot h_{s1}^{\ 2} = 0.03 \cdot in^3$$

$$a := \min(H_{guardrail}, Width_{glass}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^{\ 2} a^2} \right)} = 0.89$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^{\ 2} a^2} \right)} = 0.95$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^{\ 3} + h_2^{\ 3} + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.748 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{3}}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.760 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{3} + h_2^{3} + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.761 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{3}}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.767 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^{2} a^{2}} \right)} = 0.12$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^{2} a^{2}} \right)} = 0.12$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{3} + h_2^{3} + 12 \cdot \Gamma_{wind\_PVB} \cdot I_s \right)^{\frac{1}{3}} = 0.510 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{3}}{h_1 + 2 \cdot \Gamma_{wind\_PVB} \cdot h_{s2}} \right)^{0.5} = 0.574 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1{}^3 + h_2{}^3 + 12 \cdot \Gamma_{LL\_PVB} \cdot I_s\right)^{\frac{1}{3}} = 0.511 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}{}^3}{h_1 + 2 \cdot \Gamma_{LL\_PVB} \cdot h_{s2}}\right)^{0.5} = 0.574 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

3.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$Fr := 24ksi$$

Average Modulus of Rupture for fully tempered glass

$$\sigma_{glass\_allowable} := \frac{Fr}{4} = 6.00 \cdot ksi$$

Typical glass allowable bending stress, where factor 4 is the Safety Factor

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}{}^3}{12} \cdot W_{panel\_design} = 1.77 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}{}^2}{6} \cdot W_{panel\_design} = 4.70 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$\sigma_{applied\_LL} := \dfrac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 2.35 \cdot ksi$

Applied bending stress in glass under live load

$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$I_{glass\_LL\_deflection\_PVB} := \dfrac{h_{ef\_LL\_PVB}^{\,3}}{12} \cdot W_{panel\_design} = 0.53 \cdot in^4$

moment of inertia of glass panel for deflection check under LL (for PVB)

$S_{glass\_LL\_stress\_PVB} := \dfrac{h_{1\_ef\_\sigma\_LL\_PVB}^{\,2}}{6} \cdot W_{panel\_design} = 2.63 \cdot in^3$

Section modulus of one glass panel for stress check under LL (for PVB)

$\sigma_{applied\_LL\_PVB} := \dfrac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 4.19 \cdot ksi$

Applied bending stress in glass under live load (for PVB)

$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$

$Check_{glass\_stress\_PVB} = \text{"OK !!"}$

3.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.61 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.61 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

3.2 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.03 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.03 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

4.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(5/16" FT + 0.06" Interlayer +5/16" FT) : total thickness: 11/16", Panel width: 4 ft

$h_{1\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{2\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{v\_1} := \frac{1}{16} in = 0.06 \cdot in$ — interlayer thickness

$$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.35 \cdot in$$

ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{2} + h_{2\_1} \cdot h_{s1\_1}^{2} = 0.02 \cdot in^{3}$$

$$a_1 := \min(H_{guardrail}, Width_{glass}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.91$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.93$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.629 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.638 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.634 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.640 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.14$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.14$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.432\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}{}^3}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.485\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.432\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}{}^3}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.485\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

4.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}{}^3}{12}\cdot W_{panel\_design} = 1.02\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}{}^2}{6}\cdot W_{panel\_design} = 3.27\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 3.37 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.32 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 1.89 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 5.86 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"OK !!"}$

4.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.06 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.06 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

4.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 3.36 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 3.36 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

5.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(1/4" FT + 0.06" Interlayer +1/4" FT) : total thickness: 9/16" , Panel width: 4 ft

$h_{1\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{2\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{v\_1} := \frac{1}{16} in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.28 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}{}^2 + h_{2\_1} \cdot h_{s1\_1}{}^2 = 0.01 \cdot in^3$$

$$a_1 := \min(Height_{glass}, Width_{glass}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}{}^2 a_1{}^2} \right)} = 0.93$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_{v\_1}}{G_{SGP\_LL}\cdot {h_{s\_1}}^2 {a_1}^2}\right)} = 0.89$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left({h_{1\_1}}^3 + {h_{2\_1}}^3 + 12\cdot\Gamma_{wind\_SGP\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.490\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{{h_{ef\_w\_1}}^3}{h_{1\_1} + 2\cdot\Gamma_{wind\_SGP\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.495\cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left({h_{1\_1}}^3 + {h_{2\_1}}^3 + 12\cdot\Gamma_{LL\_SGP\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.485\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{{h_{ef\_LL\_1}}^3}{h_{1\_1} + 2\cdot\Gamma_{LL\_SGP\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.492\cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_{s\_1}\cdot h_{v\_1}}{G_{PVB\_wind}\cdot {h_{s\_1}}^2 {a_1}^2}\right)} = 0.18$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_{s\_1}\cdot h_{v\_1}}{G_{PVB\_LL}\cdot {h_{s\_1}}^2 {a_1}^2}\right)} = 0.18$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.340 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.383 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.340 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.383 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

5.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{\ 3}}{12} \cdot W_{panel\_design} = 0.46 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{\ 2}}{6} \cdot W_{panel\_design} = 1.94 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 5.70 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1}$ = "Ok !!"

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{{h_{ef\_LL\_PVB\_1}}^3}{12} \cdot W_{panel\_design} = 0.16 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{{h_{1\_ef\_\sigma\_LL\_PVB\_1}}^2}{6} \cdot W_{panel\_design} = 1.17 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 9.41 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1}$ = "NG !!"

5.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 2.37 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 2.37 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

5.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 6.85 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 6.85 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

6.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) : total thickness: 17/16" , Panel width: 4 ft

$h_{1\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{2\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{v\_1} := \frac{1}{16} in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.53 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ \ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ \ 2} = 0.07 \cdot in^3$$

$$a_1 := \min(H_{guardrail}, Width_{glass}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ \ 2} a_1^{\ 2}} \right)} = 0.86$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}{}^2 \, a_1{}^2} \right)} = 0.97$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.961 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}{}^3}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.980 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.992 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}{}^3}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.996 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}{}^2 \, a_1{}^2} \right)} = 0.09$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}{}^2 \, a_1{}^2} \right)} = 0.09$$

Shear transfer coefficient for Live load

$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.653 \cdot in$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.734 \cdot in$

effective thickness of glass for stress check under wind load (for PVB)

$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.653 \cdot in$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.734 \cdot in$

effective thickness of glass for stress check under LL load (for PVB)

6.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12} \cdot W_{panel\_design} = 3.90 \cdot in^{4}$

moment of inertia of glass panel for deflection check under LL

$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{2}}{6} \cdot W_{panel\_design} = 7.94 \cdot in^{3}$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 1.39 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 1.12 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 4.31 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 2.56 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"OK !!"}$

6.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.28 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.28 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

6.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 0.97 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 0.97 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

7.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_1 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$ ASTM E1300-16 Eq. X9.5

$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$

$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$

$I_s := h_1 \cdot h_{s2}^2 + h_2 \cdot h_{s1}^2 = 0.03 \cdot in^3$

$a := \min(H_{guardrail}, W_{panel\_design}) = 36.00 \cdot in$

$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^2 a^2} \right)} = 0.82$ Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^{2} a^{2}} \right)} = 0.91$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^{3} + h_2^{3} + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.732 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{3}}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.751 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{3} + h_2^{3} + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.753 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{3}}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.763 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^{2} a^{2}} \right)} = 0.07$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^{2} a^{2}} \right)} = 0.07$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.487\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.548\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.487\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.548\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

7.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12}\cdot W_{panel\_design} = 1.28\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6}\cdot W_{panel\_design} = 3.49\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 3.17 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.35 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 1.80 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 6.13 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = \text{"NG !!"}$

7.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.63 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.84 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

7.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.34 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 3.13 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

8.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(5/16" FT + 0.06" Interlayer +5/16" FT) : total thickness: 11/16", Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{2\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ — interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.35 \cdot in$ — ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.02 \cdot in^3$$

$$a_1 := \min(H_{guardrail}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2}\, a_1^{\ 2}} \right)} = 0.84$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.88$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.618 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.631 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.624 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.635 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.08$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_{s\_1}\cdot h_{v\_1}}{G_{PVB\_LL}\cdot h_{s\_1}^{\ 2}\, a_1^{\ 2}}\right)} = 0.08$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.408\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{\ 3}}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.460\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.408\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{\ 3}}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.460\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

8.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{\ 3}}{12}\cdot W_{panel\_design} = 0.73\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{\,2}}{6} \cdot W_{panel\_design} = 2.42 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 4.57 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1}$ = "OK !!"

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{\,3}}{12} \cdot W_{panel\_design} = 0.20 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{\,2}}{6} \cdot W_{panel\_design} = 1.27 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 8.69 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1}$ = "NG !!"

8.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.11 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.48 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

8.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 3.97 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 5.29 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

9.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(1/2" FT + 0.06" Interlayer +1/2" FT) : total thickness: 17/16" , Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{2\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{v\_1} := \frac{1}{16}in = 0.06\cdot in$ interlayer thickness

$h_{s\_1} := 0.5\cdot(h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.53\cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1}\cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.27\cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1}\cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.27\cdot in$$

$$I_{s\_1} := h_{1\_1}\cdot h_{s2\_1}^{\ 2} + h_{2\_1}\cdot h_{s1\_1}^{\ 2} = 0.07\cdot in^3$$

$$a_1 := \min(H_{guardrail}, W_{panel\_design}) = 36.00\cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_{s\_1}\cdot h_{v\_1}}{G_{SGP\_wind}\cdot h_{s\_1}^{\ 2}\, a_1^{\ 2}}\right)} = 0.77$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.94$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.936 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.966 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.985 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.993 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.05$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.05$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.629\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}{}^3}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.707\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}{}^3 + h_{2\_1}{}^3 + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.629\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}{}^3}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.707\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

9.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}{}^3}{12}\cdot W_{panel\_design} = 2.87\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}{}^2}{6}\cdot W_{panel\_design} = 5.91\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 1.87 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{vmatrix} \text{"Ok !!"} & \text{if} \quad \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.75 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 3.00 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 3.68 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{vmatrix} \text{"Ok !!"} & \text{if} \quad \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$Check_{glass\_stress\_PVB\_1} = \text{"Ok !!"}$

9.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.28 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.38 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

9.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 1.09 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 1.45 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

10.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/4" FT + 0.06" Interlayer +1/4" FT) : total thickness: 9/16" , Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{2\_1} := 0.219in$ glass minimum thickness of nominal 1/4" thick

$h_{v\_1} := \frac{1}{16} in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.28 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.14 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.01 \cdot in^3$$

$$a_1 := \min(H_{guardrail}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.88$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.82$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.483 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.491 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{\ 3} + h_{2\_1}^{\ 3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.474 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{\ 3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.487 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.11$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.11$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}{}^{3} + h_{2\_1}{}^{3} + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.318\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}{}^{3}}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.360\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}{}^{3} + h_{2\_1}{}^{3} + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.318\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}{}^{3}}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.360\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

10.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}{}^{3}}{12}\cdot W_{panel\_design} = 0.32\cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}{}^{2}}{6}\cdot W_{panel\_design} = 1.42\cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 7.78 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"NG !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.10 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 0.78 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 14.24 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"NG !!"}$

10.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 2.54 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 3.38 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

10.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 8.38 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 11.17 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

11.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9

(5/16" FT + 0.06" Interlayer +5/16" FT) : total thickness: 11/16" , Panel width: 2 ft

$W_{panel\_design} := 24in = 2.00\,ft$

$h_{1\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{2\_1} := 0.292in$ — glass minimum thickness of nominal 5/16" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ — interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.35 \cdot in$ — ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.18 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}{}^2 + h_{2\_1} \cdot h_{s1\_1}{}^2 = 0.02 \cdot in^3$$

$$a_1 := \min\left(H_{guardrail}, W_{panel\_design}\right) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}{}^2 \, a_1{}^2}\right)} = 0.71$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.77$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.590 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.615 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.602 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.622 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.04$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.04$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.388\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.437\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.388\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.437\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

11.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12}\cdot W_{panel\_design} = 0.44\cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{2}}{6}\cdot W_{panel\_design} = 1.55\cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 7.13 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP\_1} = \text{"NG !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{{h_{ef\_LL\_PVB\_1}}^3}{12} \cdot W_{panel\_design} = 0.12 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{{h_{1\_ef\_\sigma\_LL\_PVB\_1}}^2}{6} \cdot W_{panel\_design} = 0.76 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 14.48 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{cases} \text{"Ok !!"} & \text{if } \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB\_1} = \text{"NG !!"}$

11.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 1.24 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 2.48 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

11.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 4.63 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 9.27 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

12.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 2 ft

$W_{panel\_design} := 24in = 2.00\,ft$

$h_1 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^2 + h_2 \cdot h_{s1}^2 = 0.03 \cdot in^3$$

$$a := \min(H_{guardrail}, W_{panel\_design}) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^2 \, a^2} \right)} = 0.67$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^2 a^2} \right)} = 0.82$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.696 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^3}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.729 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.733 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^3}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.751 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^2 a^2} \right)} = 0.03$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^2 a^2} \right)} = 0.03$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.466\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.525\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.466\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.525\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

12.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12}\cdot W_{panel\_design} = 0.79\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6}\cdot W_{panel\_design} = 2.26\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 4.89 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.20 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 1.10 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 10.04 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = \text{"NG !!"}$

12.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.69 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 1.37 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

12.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.67 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 5.33 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

13.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(1/2" FT + 0.06" Interlayer +1/2" FT) total thickness: 19/16", Panel width: 2 ft

$$W_{panel\_design} := 24\,in = 2.00\,ft$$

$$h_1 := 0.469\,in$$ glass minimum thickness of nominal 1/2" thick

$$h_2 := 0.469\,in$$ glass minimum thickness of nominal 1/2" thick

$$h_v := \frac{1}{16}in = 0.06 \cdot in$$ interlayer thickness

$$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.53 \cdot in$$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.27 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.27 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^{\ 2} + h_2 \cdot h_{s1}^{\ 2} = 0.07 \cdot in^3$$

$$a := \min(H_{guardrail}, W_{panel\_design}) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^{\ 2}\, a^2} \right)} = 0.60$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{SGP\_LL}\cdot h_s^{2}\, a^{2}}\right)} = 0.77$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^{3} + h_2^{3} + 12\cdot\Gamma_{wind\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.881\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{3}}{h_1 + 2\cdot\Gamma_{wind\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.932\cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{3} + h_2^{3} + 12\cdot\Gamma_{LL\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.937\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{3}}{h_1 + 2\cdot\Gamma_{LL\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.966\cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_wind}\cdot h_s^{2}\, a^{2}}\right)} = 0.02$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_LL}\cdot h_s^{2}\, a^{2}}\right)} = 0.02$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.609\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.684\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.609\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.684\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

13.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12}\cdot W_{panel\_design} = 1.64\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6}\cdot W_{panel\_design} = 3.73\cdot in^3$$

Section modulus of one glass panel for stress check under LL

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$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 2.96 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.45 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 1.87 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 5.90 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = \text{"OK !!"}$

14.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.33 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.66 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

14.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 1.20 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^3}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.39 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

Job Description

This worksheet is for the structural design of the 72" high glass guardrail with varied thickness for Carvart Glass product, the following items are Included:

1. Constants.
2. glass guardrail live load
3. 13/16" thick glass panel (4ft wide)
4. 17/16" thick glass panel (4ft wide)
5. 13/16" thick glass panel (3ft wide)
6. 17/16" thick glass panel (3ft wide)
7. 17/16" thick glass panel (2ft wide)

Design Notes and Results

1.) the scope of work: glass panel strength/deflection design,

2.) No strength check of existing structure or sybstrate or items by others are in the scope of work.

3.) work this design with glass railing product.

References

1.) AISC steel construction Manual. 15th Edition
2.) NYC building construction Code. 2014
3.) ACI 318-14 Chapter 17
4.) ASTM E1300-16: Standard Practice for Determining load Resistance of Glass in Buildings

Project: **Carvart Interior Glass Guardrail Design**
Subject: **72" high Guardrail Check**
Designed by:J. W
Date: 02/15/2021

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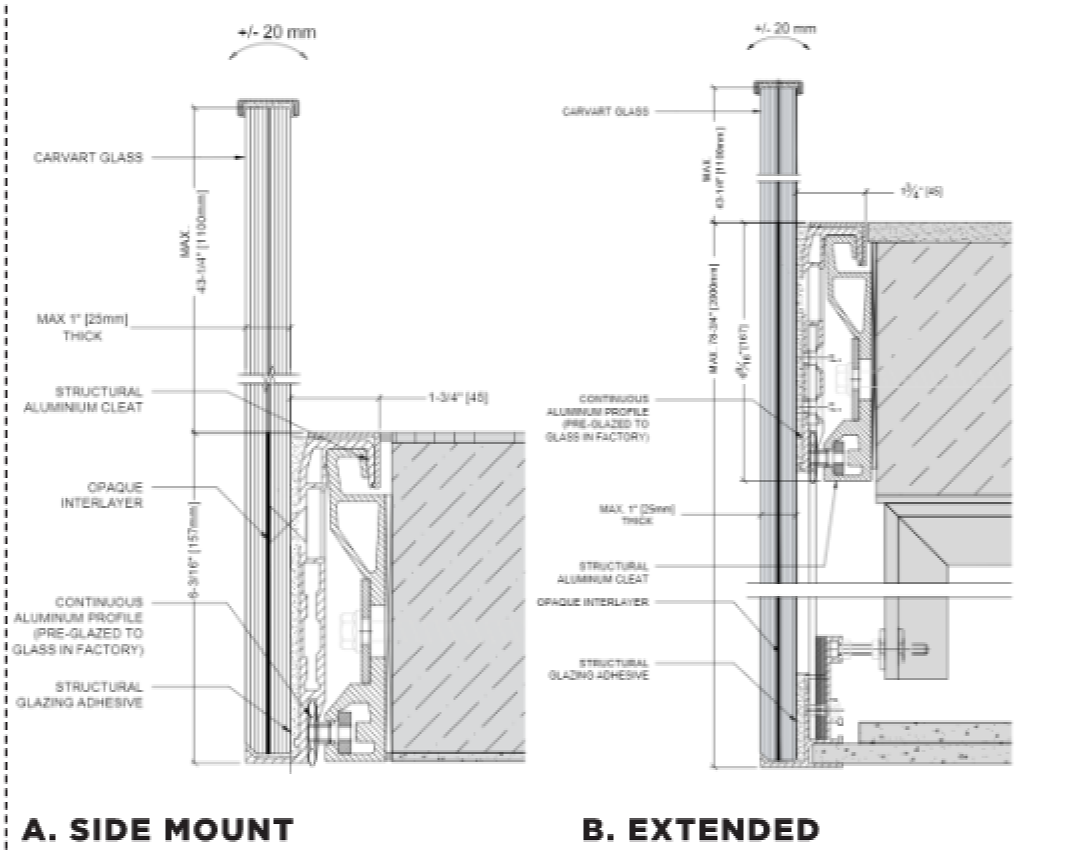

1. Constants

$f_c := 2500psi$ Design Compressive Strength of concrete (assumed)

$\gamma_{glass} := 160pcf$ Density of glass

$\gamma_{stl} := 490pcf$ Density of Steel

1.2 Dead Load (DC)

$Height_{glass} := 78in + \frac{3}{4}in + 43in + \frac{1}{4}in = 10.17\,ft$ max. glass panel height

$Width_{glass} := 48in = 4.00\,ft$ yypical glass panel width

$t_{glass\_max} := \frac{17}{16}in$ max. Glass panel thickness (for dead load calculatin purpose)

$H_{guardrail} := 72in = 6.00\,ft$ height of glass guardrail (top of guardrail to finished floor)

Glass panel Dead Load:

$DL_{glasspanel} := 1.1\gamma_{glass} \cdot Height_{glass} \cdot t_{glass\_max} \cdot Width_{glass} = 633.72\,lbf$

2.1. Live Load (interior glass panel)

the following live load is applied on the interior glass guardrail:

guardrail railing: 50 plf in any direction applied on top of guardrail, or 200 lbf concentrated live load

$W_{panel\_design} := 48in = 4.00\,ft$

design panel width for Live load

$V_{glass\_applied} := \max\left(50plf \cdot W_{panel\_design}, 200lbf\right) = 200.00\,lbf$

$M_{glass\_applied} := V_{glass\_applied} \cdot \left(H_{guardrail}\right) = 14.40 \cdot kip \cdot in$

max. bending moment at cener of structural silicone below the floor

2.2 lateral Load (applicable to glass panel, not for guardrail)

the following lateral load is applied on the infill of glass panel:

lateral load of 5 psf applied normal to the panels on the full extent of the solid vertical surface.

$UL_{lateral} := 5psf$

lateral load on glass panel (not for guardrail)

3.1 Glass Panel Effective thickness for stress and deflection check Per ASTM E1300-16 X9

(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 4 ft

$h_1 := 0.355in$	glass minimum thickness of nominal 3/8" thick
$h_2 := 0.355in$	glass minimum thickness of nominal 3/8" thick
$h_v := \frac{1}{16}in = 0.06 \cdot in$	interlayer thickness
$E_{glass} := 10399ksi$	glass Young's modulus of elasticity
$G_{SGP\_wind} := 3828psi$	interlayer complex shear modulus for 3S/122 F degree for SGP interlayer for wind load
$G_{SGP\_LL} := 8686psi$	interlayer complex shear modulus for 1 hour /86 F degree for SGP interlayer for live load
$G_{PVB\_wind} := 63.8psi$	interlayer complex shear modulus for 3S/122 F degree for PVB interlayer for wind load
$G_{PVB\_LL} := 63.9psi$	interlayer complex shear modulus for 1 hour/86 F degree for PVB interlayer for live load

G value reference:
https://www.trosifol.com/glass-calculator/?no_cache=1&tx_glasscalculator_calculator%5Baction%5D=showCase1&tx_glasscalculator_calculator%5Bcontroller%5D=Start&cHash=0a59bd8a690a1465001bfbc556618a00

$$h_s := 0.5\cdot(h_1 + h_2) + h_v = 0.42\cdot in$$

ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21\cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21\cdot in$$

$$I_s := h_1 \cdot {h_{s2}}^2 + h_2 \cdot {h_{s1}}^2 = 0.03\cdot in^3$$

$$a := \min(Height_{glass}, Width_{glass}) = 48.00\cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s \cdot h_v}{G_{SGP\_wind}\cdot {h_s}^2 a^2}\right)} = 0.89$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s \cdot h_v}{G_{SGP\_LL}\cdot {h_s}^2 a^2}\right)} = 0.95$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left({h_1}^3 + {h_2}^3 + 12\cdot\Gamma_{wind\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.748\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}{}^{3}}{h_1 + 2\cdot\Gamma_{wind\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.760\cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1{}^{3} + h_2{}^{3} + 12\cdot\Gamma_{LL\_SGP}\cdot I_s\right)^{\frac{1}{3}} = 0.761\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}{}^{3}}{h_1 + 2\cdot\Gamma_{LL\_SGP}\cdot h_{s2}}\right)^{0.5} = 0.767\cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_wind}\cdot h_s{}^{2}\, a^{2}}\right)} = 0.12$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6\cdot\left(\frac{E_{glass}\cdot I_s\cdot h_v}{G_{PVB\_LL}\cdot h_s{}^{2}\, a^{2}}\right)} = 0.12$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1{}^{3} + h_2{}^{3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.510\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}{}^{3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.574\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.511\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.574\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

3.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$Fr := 24ksi$$

Average Modulus of Rupture for fully tempered glass

$$\sigma_{glass\_allowable} := \frac{Fr}{4} = 6.00\cdot ksi$$

Typical glass allowable bending stress, where factor 4 is the Safety Factor

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12}\cdot W_{panel\_design} = 1.77\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6}\cdot W_{panel\_design} = 4.70\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 3.06 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_SGP} = \text{"OK !!"}$$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.53 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 2.63 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 5.47 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$$Check_{glass\_stress\_PVB} = \text{"OK !!"}$$

3.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 1.36 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 1.36 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

3.2 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 4.50 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 4.50 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

4.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) : total thickness: 17/16" , Panel width: 4 ft

$h_{1\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{2\_1} := 0.469in$ glass minimum thickness of nominal 1/2" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.53 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\ 2} + h_{2\_1} \cdot h_{s1\_1}^{\ 2} = 0.07 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 48.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\ 2} a_1^{\ 2}} \right)} = 0.86$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.97$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.961 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.980 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.992 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.996 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.09$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.09$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}{}^{3} + h_{2\_1}{}^{3} + 12\cdot\Gamma_{wind\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.653\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}{}^{3}}{h_{1\_1} + 2\cdot\Gamma_{wind\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.734\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}{}^{3} + h_{2\_1}{}^{3} + 12\cdot\Gamma_{LL\_PVB\_1}\cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.653\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}{}^{3}}{h_{1\_1} + 2\cdot\Gamma_{LL\_PVB\_1}\cdot h_{s2\_1}}\right)^{0.5} = 0.734\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

4.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}{}^{3}}{12}\cdot W_{panel\_design} = 3.90\cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}{}^{2}}{6}\cdot W_{panel\_design} = 7.94\cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$\sigma_{applied\_LL\_1} := \dfrac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 1.81 \cdot ksi$

Applied bending stress in glass under live load

$Check_{glass\_stress\_SGP\_1} := \begin{array}{|l} \text{"OK !!"} \ \text{ if } \ \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} \ \text{ otherwise} \end{array}$

$Check_{glass\_stress\_SGP\_1} = \text{"OK !!"}$

$I_{glass\_LL\_deflection\_PVB\_1} := \dfrac{h_{ef\_LL\_PVB\_1}^{\ 3}}{12} \cdot W_{panel\_design} = 1.12 \cdot in^4$

moment of inertia of glass panel for deflection check under LL (for PVB)

$S_{glass\_LL\_stress\_PVB\_1} := \dfrac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{\ 2}}{6} \cdot W_{panel\_design} = 4.31 \cdot in^3$

Section modulus of one glass panel for stress check under LL (for PVB)

$\sigma_{applied\_LL\_PVB\_1} := \dfrac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 3.34 \cdot ksi$

Applied bending stress in glass under live load (for PVB)

$Check_{glass\_stress\_PVB\_1} := \begin{array}{|l} \text{"OK !!"} \ \text{ if } \ \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} \ \text{ otherwise} \end{array}$

$Check_{glass\_stress\_PVB\_1} = \text{"OK !!"}$

4.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.61 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.61 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

4.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 2.14 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 2.14 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

5.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(3/8" FT + 0.06" Interlayer +3/8" FT) total thickness: 13/16", Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_1 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_2 := 0.355in$ glass minimum thickness of nominal 3/8" thick

$h_v := \frac{1}{16}in = 0.06 \cdot in$ interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.42 \cdot in$ ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.21 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.21 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^2 + h_2 \cdot h_{s1}^2 = 0.03 \cdot in^3$$

$$a := \min(Height_{glass}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^2 \, a^2} \right)} = 0.82$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^{2} a^{2}} \right)} = 0.91$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^{3} + h_2^{3} + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.732 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^{3}}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.751 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^{3} + h_2^{3} + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.753 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^{3}}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.763 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^{2} a^{2}} \right)} = 0.07$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^{2} a^{2}} \right)} = 0.07$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{wind\_PVB} \cdot I_s\right)^{\frac{1}{3}} = 0.487 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\,3}}{h_1 + 2 \cdot \Gamma_{wind\_PVB} \cdot h_{s2}}\right)^{0.5} = 0.548 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12 \cdot \Gamma_{LL\_PVB} \cdot I_s\right)^{\frac{1}{3}} = 0.487 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\,3}}{h_1 + 2 \cdot \Gamma_{LL\_PVB} \cdot h_{s2}}\right)^{0.5} = 0.548 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

5.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\,3}}{12} \cdot W_{panel\_design} = 1.28 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\,2}}{6} \cdot W_{panel\_design} = 3.49 \cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 4.13 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP}$ = "OK !!"

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{\ 3}}{12} \cdot W_{panel\_design} = 0.35 \cdot in^4$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{\ 2}}{6} \cdot W_{panel\_design} = 1.80 \cdot in^3$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 7.99 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB}$ = "NG !!"

5.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 1.40 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 1.87 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

5.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 5.19 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 6.92 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

6.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) : total thickness: 17/16" , Panel width: 3 ft

$W_{panel\_design} := 36in = 3.00\,ft$

$h_{1\_1} := 0.469in$ — glass minimum thickness of nominal 1/2" thick

$h_{2\_1} := 0.469in$ — glass minimum thickness of nominal 1/2" thick

$h_{v\_1} := \frac{1}{16}in = 0.06 \cdot in$ — interlayer thickness

$h_{s\_1} := 0.5 \cdot (h_{1\_1} + h_{2\_1}) + h_{v\_1} = 0.53 \cdot in$ — ASTM E1300-16 Eq. X9.5

$$h_{s1\_1} := \frac{h_{s\_1} \cdot h_{1\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$h_{s2\_1} := \frac{h_{s\_1} \cdot h_{2\_1}}{h_{1\_1} + h_{2\_1}} = 0.27 \cdot in$$

$$I_{s\_1} := h_{1\_1} \cdot h_{s2\_1}^{\;2} + h_{2\_1} \cdot h_{s1\_1}^{\;2} = 0.07 \cdot in^3$$

$$a_1 := \min(Height_{glass}, W_{panel\_design}) = 36.00 \cdot in$$

$$\Gamma_{wind\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{SGP\_wind} \cdot h_{s\_1}^{\;2}\, a_1^{\;2}} \right)} = 0.77$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_{v\_1}}{G_{SGP\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.94$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.936 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind\_1} := \left(\frac{h_{ef\_w\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.966 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_SGP\_1} \cdot I_{s\_1} \right)^{\frac{1}{3}} = 0.985 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL\_1} := \left(\frac{h_{ef\_LL\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_SGP\_1} \cdot h_{s2\_1}} \right)^{0.5} = 0.993 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_wind} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.05$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB\_1} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_{s\_1} \cdot h_{v\_1}}{G_{PVB\_LL} \cdot h_{s\_1}^{2} a_1^{2}} \right)} = 0.05$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{wind\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.629 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb\_1} := \left(\frac{h_{ef\_w\_pvb\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{wind\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.707 \cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB\_1} := \left(h_{1\_1}^{3} + h_{2\_1}^{3} + 12 \cdot \Gamma_{LL\_PVB\_1} \cdot I_{s\_1}\right)^{\frac{1}{3}} = 0.629 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB\_1} := \left(\frac{h_{ef\_LL\_PVB\_1}^{3}}{h_{1\_1} + 2 \cdot \Gamma_{LL\_PVB\_1} \cdot h_{s2\_1}}\right)^{0.5} = 0.707 \cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

6.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP\_1} := \frac{h_{ef\_LL\_1}^{3}}{12} \cdot W_{panel\_design} = 2.87 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress\_1} := \frac{h_{1\_ef\_\sigma\_LL\_1}^{2}}{6} \cdot W_{panel\_design} = 5.91 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_1}} = 2.44 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP\_1} := \begin{vmatrix} \text{"Ok !!"} & \text{if} \quad \sigma_{applied\_LL\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$Check_{glass\_stress\_SGP\_1} = \text{"Ok !!"}$

$$I_{glass\_LL\_deflection\_PVB\_1} := \frac{h_{ef\_LL\_PVB\_1}^{3}}{12} \cdot W_{panel\_design} = 0.75 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB\_1} := \frac{h_{1\_ef\_\sigma\_LL\_PVB\_1}^{2}}{6} \cdot W_{panel\_design} = 3.00 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB\_1} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB\_1}} = 4.80 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB\_1} := \begin{vmatrix} \text{"Ok !!"} & \text{if} \quad \sigma_{applied\_LL\_PVB\_1} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$Check_{glass\_stress\_PVB\_1} = \text{"Ok !!"}$

6.3 Glass deflection Check (SGP interlayer)

Note:
NYC building code 2014 edition has no limit/requirement for guardrail deflection under design live load

$$\Delta_{LL\_glass\_SGP\_50plf\_1} := \frac{\left(50plf \cdot W_{panel\_design}\right) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.63 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP\_1}} = 0.83 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

6.4 Glass deflection of glass guardrail with PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf\_1} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 2.40 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf\_1} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB\_1}} = 3.20 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

7.1 Glass Panel Effective thickness for stress and deflection check
Per ASTM E1300-16 X9
(1/2" FT + 0.06" Interlayer +1/2" FT) total thickness: 17/16", Panel width: 2 ft

$W_{panel\_design} := 24 in = 2.00 ft$

$h_1 := 0.469 in$ — glass minimum thickness of nominal 1/2" thick

$h_2 := 0.469 in$ — glass minimum thickness of nominal 1/2" thick

$h_v := \frac{1}{16} in = 0.06 \cdot in$ — interlayer thickness

$h_s := 0.5 \cdot (h_1 + h_2) + h_v = 0.53 \cdot in$ — ASTM E1300-16 Eq. X9.5

$$h_{s1} := \frac{h_s \cdot h_1}{h_1 + h_2} = 0.27 \cdot in$$

$$h_{s2} := \frac{h_s \cdot h_2}{h_1 + h_2} = 0.27 \cdot in$$

$$I_s := h_1 \cdot h_{s2}^{\ 2} + h_2 \cdot h_{s1}^{\ 2} = 0.07 \cdot in^3$$

$$a := \min(Height_{glass}, W_{panel\_design}) = 24.00 \cdot in$$

$$\Gamma_{wind\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_wind} \cdot h_s^{\ 2} a^2} \right)} = 0.60$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_SGP} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{SGP\_LL} \cdot h_s^2 a^2} \right)} = 0.77$$

Shear transfer coefficient for Live load

$$h_{ef\_w} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{wind\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.881 \cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_wind} := \left(\frac{h_{ef\_w}^3}{h_1 + 2 \cdot \Gamma_{wind\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.932 \cdot in$$

effective thickness of glass for stress check under wind load

$$h_{ef\_LL} := \left(h_1^3 + h_2^3 + 12 \cdot \Gamma_{LL\_SGP} \cdot I_s \right)^{\frac{1}{3}} = 0.937 \cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6

$$h_{1\_ef\_\sigma\_LL} := \left(\frac{h_{ef\_LL}^3}{h_1 + 2 \cdot \Gamma_{LL\_SGP} \cdot h_{s2}} \right)^{0.5} = 0.966 \cdot in$$

effective thickness of glass for stress check under LL load

$$\Gamma_{wind\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_wind} \cdot h_s^2 a^2} \right)} = 0.02$$

Shear transfer coefficient for wind load per ASTM E1300-16 Eq. X9.1

$$\Gamma_{LL\_PVB} := \frac{1}{1 + 9.6 \cdot \left(\frac{E_{glass} \cdot I_s \cdot h_v}{G_{PVB\_LL} \cdot h_s^2 a^2} \right)} = 0.02$$

Shear transfer coefficient for Live load

$$h_{ef\_w\_pvb} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{wind\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.609\cdot in$$

effective glass thickness for deflection under wind load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_wind\_pvb} := \left(\frac{h_{ef\_w\_pvb}^{\;3}}{h_1 + 2\cdot\Gamma_{wind\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.684\cdot in$$

effective thickness of glass for stress check under wind load (for PVB)

$$h_{ef\_LL\_PVB} := \left(h_1^{\,3} + h_2^{\,3} + 12\cdot\Gamma_{LL\_PVB}\cdot I_s\right)^{\frac{1}{3}} = 0.609\cdot in$$

effective glass thickness for deflection under LL load. ASTM E1300-16 Eq. X9.6 (for PVB)

$$h_{1\_ef\_\sigma\_LL\_PVB} := \left(\frac{h_{ef\_LL\_PVB}^{\;3}}{h_1 + 2\cdot\Gamma_{LL\_PVB}\cdot h_{s2}}\right)^{0.5} = 0.684\cdot in$$

effective thickness of glass for stress check under LL load (for PVB)

7.2 Glass Panel Strength Design (ASD method) per NYC Building Code 2014 Edition Chapter 24 item 2407.1.1 (for both SGP & PVB interlayer)

$$I_{glass\_LL\_deflection\_SGP} := \frac{h_{ef\_LL}^{\;3}}{12}\cdot W_{panel\_design} = 1.64\cdot in^4$$

moment of inertia of glass panel for deflection check under LL

$$S_{glass\_LL\_stress} := \frac{h_{1\_ef\_\sigma\_LL}^{\;2}}{6}\cdot W_{panel\_design} = 3.73\cdot in^3$$

Section modulus of one glass panel for stress check under LL

$$\sigma_{applied\_LL} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress}} = 3.86 \cdot ksi$$

Applied bending stress in glass under live load

$$Check_{glass\_stress\_SGP} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_SGP} = \text{"OK !!"}$

$$I_{glass\_LL\_deflection\_PVB} := \frac{h_{ef\_LL\_PVB}^{3}}{12} \cdot W_{panel\_design} = 0.45 \cdot in^{4}$$

moment of inertia of glass panel for deflection check under LL (for PVB)

$$S_{glass\_LL\_stress\_PVB} := \frac{h_{1\_ef\_\sigma\_LL\_PVB}^{2}}{6} \cdot W_{panel\_design} = 1.87 \cdot in^{3}$$

Section modulus of one glass panel for stress check under LL (for PVB)

$$\sigma_{applied\_LL\_PVB} := \frac{M_{glass\_applied}}{S_{glass\_LL\_stress\_PVB}} = 7.68 \cdot ksi$$

Applied bending stress in glass under live load (for PVB)

$$Check_{glass\_stress\_PVB} := \begin{cases} \text{"OK !!"} & \text{if } \sigma_{applied\_LL\_PVB} \le \sigma_{glass\_allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{glass\_stress\_PVB} = \text{"NG !!"}$

7.3 Glass deflection Check (SGP interlayer)

$$\Delta_{LL\_glass\_SGP\_50plf} := \frac{(50plf \cdot W_{panel\_design}) \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 0.73 \cdot in$$

glass deflection (with SGP interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_SGP\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_SGP}} = 1.46 \cdot in$$

glass deflection (with SGP interlayer) under 200 lbf concentrated live load

7.4 Glass deflection of glass guardrail wuth PVB interlayer

$$\Delta_{LL\_glass\_PVB\_50plf} := \frac{50plf \cdot W_{panel\_design} \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 2.65 \cdot in$$

glass deflection (with PVB interlayer) under 50 plf live load

$$\Delta_{LL\_glass\_PVB\_200lbf} := \frac{200lbf \cdot H_{guardrail}^{3}}{3 \cdot E_{glass} \cdot I_{glass\_LL\_deflection\_PVB}} = 5.30 \cdot in$$

glass deflection (with PVB interlayer) under 200 lbf concentrated live load

Project: **Glass guardrail Product Silicone & Anchor**
Subject: **Silicone & COncrete Anchor Design**
Designed by:J. W
Date: 02/15/2021

Index No. .
Job. No. .

Job Description

This worksheet is for the structural design of the glass guardrail silicone and concrete anchor for Carvart glass product including PLAN, LEVEL and UNI.

References

1.) AISC steel construction Manual. 15th Edition
2.) NYC building construction Code. 2014
3.) ACI 318-14 Chapter 17
4.) ASTM E1300-16: Standard Practice for Determining load Resistance of Glass in Buildings

Appendix

1.) HILTI ESR_1917 Report:
https://www.icc-es.org/wp-content/uploads/report-directory/ESR-1917.pdf

Concrete Deck Assumption:

1. Normal weight minimum 6" thick concrete strutcural slab, cracked concrete is assumed with concrete compression strength Fc' = 2500psi.
2. min. 6" thick structural concrete slab (without metal deck) is required. and solid slab without hollow is required.

Recommended Concrete Anchor:

Recommended anchor for glassRAILING>PLAN: A. Side Mount:

1. 1/2" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 3.75" concrete embedment @ 12" max. spacing with minimum 2.5" concrete edge distance.
2. applicable to 43" high glass guardrail with minimum 4 ft wide.

Recommended anchor for glassRAILING>PLAN: B. Etended:

1. 3/8" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 2.5" concrete embedment @ 16" max. spacing with minimum 2.5" concrete edge distance.
2. applicable to 43" high glass guardrail with minimum 4 ft wide.

Recommended anchor for glassRAILING>UNI: A. Side Mount:

1. 1/2" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 3.75" concrete embedment @ 9" max. spacing with minimum 3.5" concrete edge distance.
2. applicable to 55.125" high glass guardrail with minimum 4 ft wide.

Recommended anchor for glassRAILING>UNI: A. Top Mount:

1. 1/2" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 3.75" concrete embedment @ 12" max. spacing with minimum 3.5" concrete edge distance.
2. applicable to 55.125" high glass guardrail with minimum 4 ft wide.

Recommended anchor for glassRAILING>LEVEL:

1. 3/8" diameter HILITI KWIK BOLT TZ (KB-TZ) carbon steel anchor with minimum 2.5" concrete embedment @ 16" max. spacing with minimum 2.5" concrete edge distance.
2. applicable to 55" high glass guardrail with minimum 4 ft wide.

Project: **Glass guardrail Product Silicone & Anchor**
Subject: **Silicone & COncrete Anchor Design**
Designed by:J. W
Date: 02/15/2021

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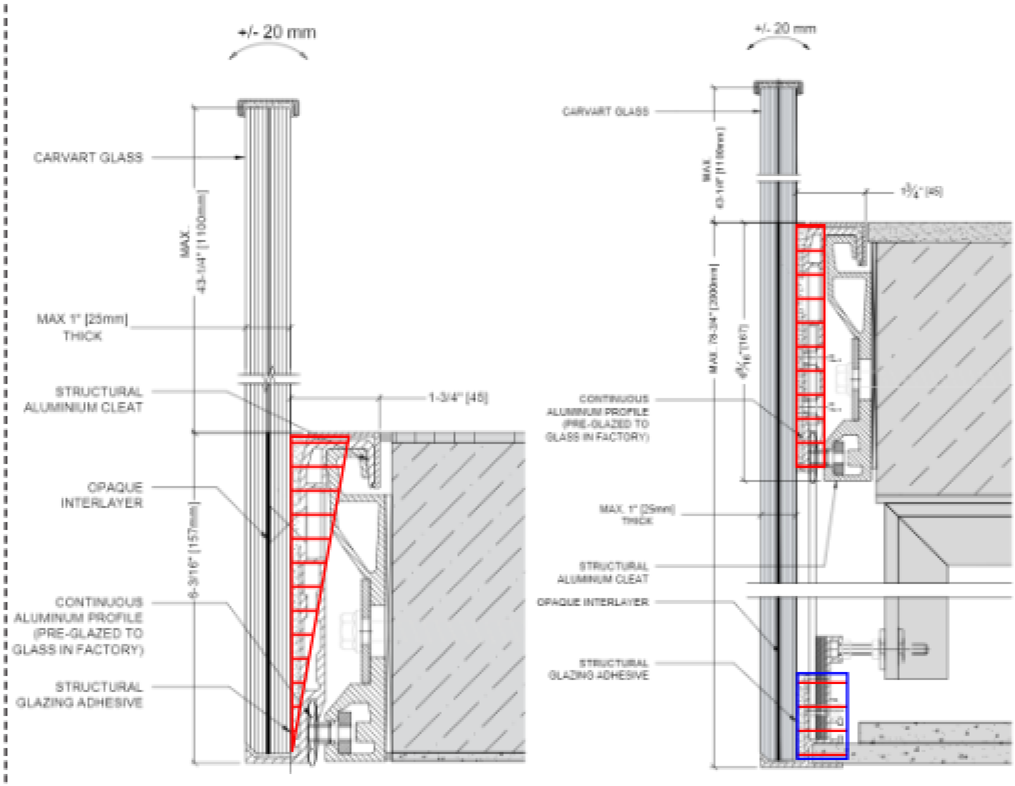
glassRAILINGS>PLAN



A. SIDE MOUNT **B. EXTENDED**

1.1 Constants

$\gamma_{glass} := 160pcf$ — Density of glass

$\gamma_{stl} := 490pcf$ — Density of Steel

1.2 Dead Load (DC) for anchor design

$Height_{glass} := 78in + \frac{3}{4}in + 43in + \frac{1}{4}in = 10.17\,ft$ — max. glass panel height

$Width_{glass} := 43in = 3.58\,ft$ — Typical glass panel width

$t_{glass\_max} := 1in$ — max. Glass panel thickness (for dead load calculatin purpose)

$H_{guardrail} := 43in + \frac{1}{4}in = 3.60\,ft$ — height of glass guardrail (top of guardrail to finished floor)

Glass panel Dead Load:

$$DL_{glasspanel} := 1.1\gamma_{glass} \cdot Height_{glass} \cdot t_{glass\_max} \cdot Width_{glass} = 534.31\,lbf$$

1.3. Live Load (interior glass panel)

the following live load is applied on the glass panel:

guardrail railing: 50 plf in any direction applied on top of guardrail, or 200 lbf concentrated live load

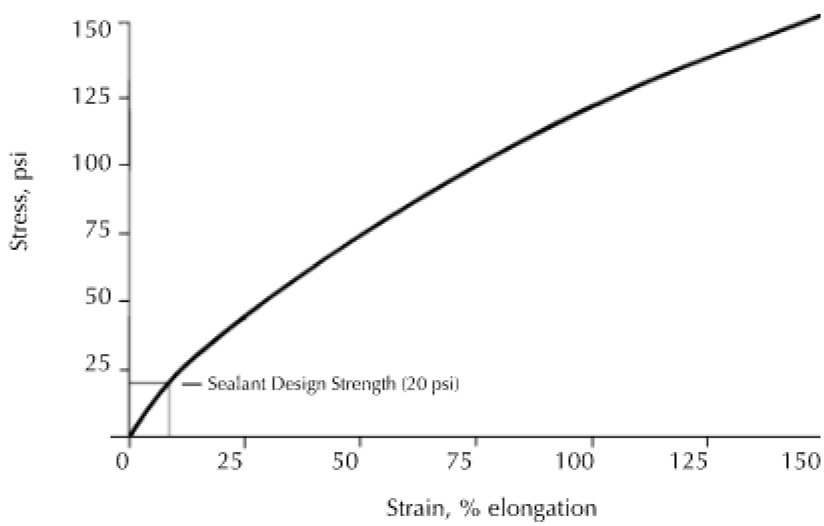
$ULL := 50plf$ uniformly live load on top of guardrail

$PLL := 200lbf$ cocentrated live load on top of guardrail

$H_{guardail} := 43.25in$ height of guardrail

2.1 Structural Silicone Allowable strain and tension/shear capacity

Note:
1 .structural silicone DOWSIL 2-part Curing Agent is checked here, other products such as 121, DOWSIL 795, and DOWSIL 995 are applicable.
2. silicone design here is for typcial live load and temperature (86 F degree) condition.
3. silicone strain-stress of 795 below is listed for reference.



$\varepsilon_{allowable\_LL} := 0.15$ — Allowable live load structural silicone elongation strain

$\sigma_{allowable} := 20psi$ — Allowable structural silicone stress

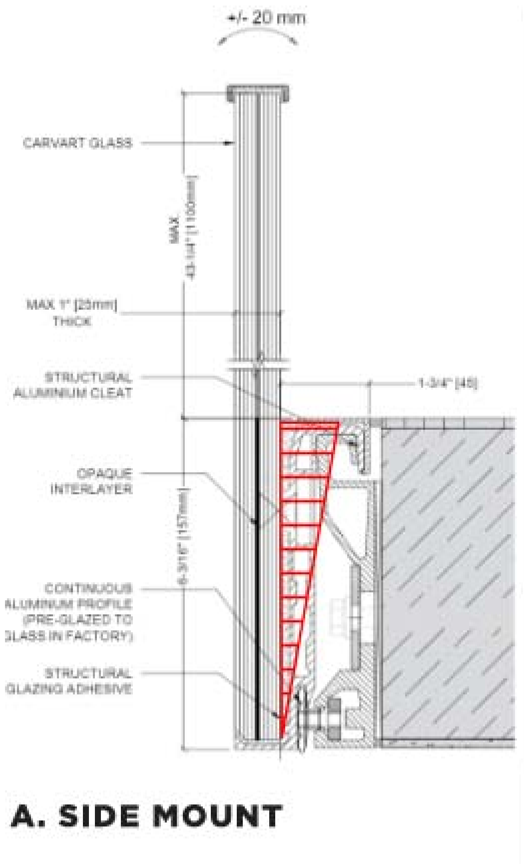
$\sigma_{allowable\_Seismic} := 20psi$ — Allowable structural silicone stress under seismic (assumed)

$\tau_{allowable\_LL} := 20psi$ — Allowable structural silicone stress under dead load

$\tau_{allowable\_DL} := 1psi$ — Allowable structural silicone shear stress under dead load

2.2 Structural Silicone Check for glassRAILINGS>PLAN:

A. SIDE MOUNT



Note:

1. for silicone stress check under live load, the glass panel is assumed to be supported at bottom.
2. see above for the silicone stress distribution.

$d_{silicone} := 6in$

typcial depth of silicone below the floor (assumed)

$Width_{panel1} := 4ft$

free standing glass guardrail width (>= 4ft)

$$\sigma_{silicone\_LL\_4ft} := \frac{\max\left(ULL \cdot Width_{panel1}, PLL\right) \cdot \left(H_{guardail} + 6in + \frac{3}{16}in\right)}{Width_{panel1} \cdot \frac{d_{silicone}^{2}}{3}} = 17.17\ psi$$

applied tension/compression stress on silicone under live load

$Width_{panel2} := 3.5ft$

free standing glass guardrail width (3.5ft)

$$\sigma_{silicone\_LL\_3.5ft} := \frac{\max\left(ULL \cdot Width_{panel2}, PLL\right) \cdot \left(H_{guardail} + 6in + \frac{3}{16}in\right)}{Width_{panel2} \cdot \frac{d_{silicone}^{2}}{3}} = 19.62\ psi$$

applied tension/compression stress on silicone under live load

$$Check_{silicone\_stress\_Plan\_Side\_mount} := \begin{cases} \text{"OK !!"} & \text{if } \max\left(\sigma_{silicone\_LL\_3.5ft}, \sigma_{silicone\_LL\_4ft}\right) \le \sigma_{allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{silicone\_stress\_Plan\_Side\_mount} = \text{"OK !!"}$

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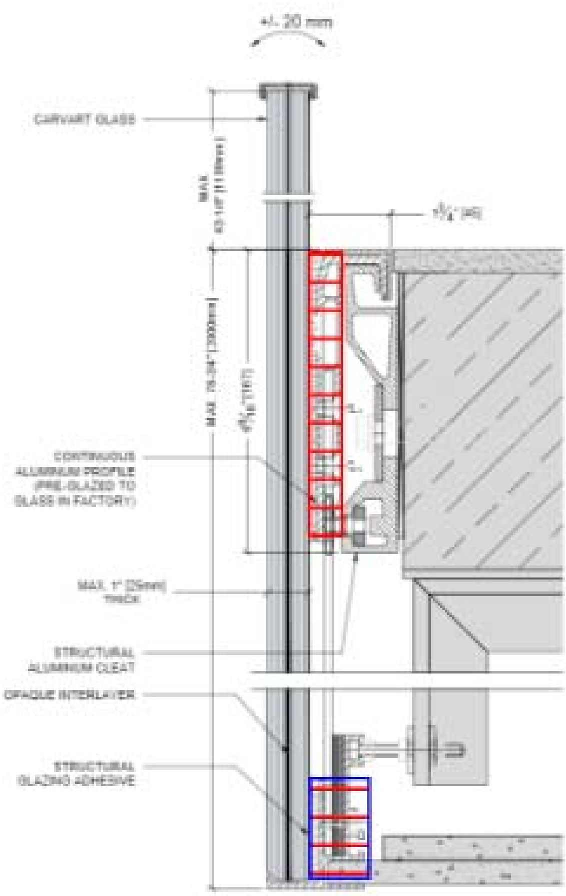
2.3 Structural Silicone Check for glassRAILINGS>PLAN: B. EXTENDED



B. EXTENDED

$d_{silicone\_top} := 6in$ — typcial depth of silicone below the floor (assumed)

$d_{silicone\_bot} := 2.5in$ — typcial depth of silicone at the bottom (assumed)

Note:
1. for silicone stress check under live load, the glass panel is assumed to be supported at silicone top and bottom.
2. see above for the silicone stress distribution.

$dist_{silicone} := 24in$

distance between top silicone and bottom silicone (assumed)

$Width_{panel3} := 4ft$

free standing glass guardrail width (>= 4ft)

$$\sigma_{silicone\_LL\_B\_4ft} := \frac{\max(ULL \cdot Width_{panel3}, PLL) \cdot (H_{guardail} + dist_{silicone})}{Width_{panel3} \cdot d_{silicone\_bot} \cdot dist_{silicone}} = 4.67\,psi$$

applied tension/compression stress on silicone under live load

$Width_{panel4} := 2ft$

free standing glass guardrail width (3.5ft)

$$\sigma_{silicone\_LL\_B\_2ft} := \frac{\max(ULL \cdot Width_{panel4}, PLL) \cdot (H_{guardail} + dist_{silicone})}{Width_{panel4} \cdot d_{silicone\_bot} \cdot dist_{silicone}} = 9.34\,psi$$

applied tension/compression stress on silicone under live load

$$Check_{silicone\_stress\_Plan\_Extended} := \begin{cases} \text{"OK !!"} & \text{if } \max(\sigma_{silicone\_LL\_B\_4ft}, \sigma_{silicone\_LL\_B\_2ft}) \le \sigma_{allowable} \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Check_{silicone\_stress\_Plan\_Extended} = \text{"OK !!"}$

THE DOW CHEMICAL COMPANY
SALES SPECIFICATION

Date Printed: 2021-02-13

Effective Date: 2019-03-11
Supersedes Date: 2018-11-09

Name: DOWSIL™ 2-Part Curing Agent Black

Specification Number: 000000843795

Shelf Life

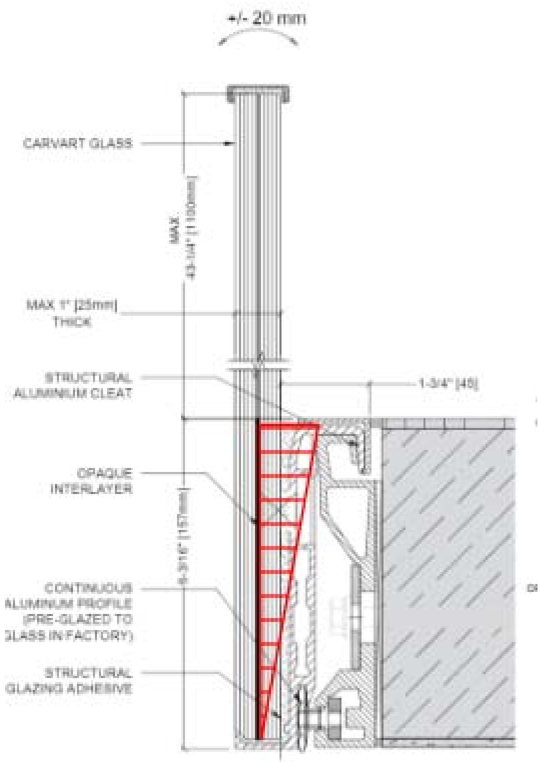
Container Type	Conditions of Handling	Conditions of Storage	Shelf Life	Deterioration Characteristics
All Approved Packaging	Avoid freezing	Store BELOW 32C/90F	360 Days	

Final Testing Requirements

Test and Test Condition	Limit	Unit	Method	Note
Appearance	Pass		CTM0176	
Viscosity, RVT, Spindle 7 @ 20 RPM	80000 Max	mPa.s	CTM0050	
Snap Time	20 — 60	min	CTM0092A	
Durometer, 7d/RT	30 — 50	ShoreA	CTM0099	
Tensile, 7d/RT	200 — 400	psi	CTM0137A	
Elongation, 7d/RT	300 — 700	%	CTM0137A	

READ PRECAUTIONARY INFORMATION AND MATERIAL SAFETY SHEETS. THIS PRODUCT IS SHIPPED IN COMPLIANCE WITH APPLICABLE LAWS AND REGULATIONS REGARDING CLASSIFICATION, PACKAGING, SHIPPING AND LABELING.

3.0 Design of Concrete Anchor *anchor*
(glassRAILING>PLAN)



A. SIDE MOUNT

Note
1. As a illustrative sample here, HILTI KWIK BOLT TZ (KB-TZ) carbon steel anchor is selected for design.
2. it is contractor engineer's responsibility/libaility to design the anchor. the design here is a recommendation .

Project: **Glass guardrail Product Silicone & Anchor**
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$W_{guardail} := 4ft$ width of guardrail panel

$Spacing_{anchor1} := 12in$ spacing of lateral anchor (case 1)

$N_{anchor} := floor\left(\frac{W_{guardail}}{Spacing_{anchor1}}\right) = 4.00$ Number of anchor for one glass panel

$Edge_{anchor} := 2.5in$ minimum concrete edge distance

$DL_{paneL\_plan\_A} := 160pcf \cdot 1in \cdot W_{guardail} \cdot (H_{guardail} + 6.25in) \cdot 1.2 = 264.00\,lbf$ dead load applied on one glass panel (assumed in conservative side)

$LL_{panel} := max(PLL, ULL \cdot W_{guardail}) = 200.00\,lbf$ max. live load on one panel

$T_{anchor\_applied} := \frac{LL_{panel} \cdot (H_{guardail} + 6.25in)}{Edge_{anchor} \cdot N_{anchor}} = 990.00\,lbf$ tension load on one anchor

$V_{anchor\_applied} := \frac{DL_{paneL\_plan\_A} + LL_{panel}}{N_{anchor}} = 116.00\,lbf$ shear load on one anchor

ESR – 1917

1/2" Dia. anchor bolt with 3.75" embedment

$d_{anchor} := \frac{1}{2} in$ — anchor bolt size

$Embedment_{anchor} := 3.25in$ — anchor bolt embedment depth

$V_{anchor\_factored} := V_{anchor\_applied} \cdot 1.6 = 0.19 \cdot kip$ — total shear factored load on one anchor, (1.6 factor is used to convert load from ASD to Strength Method) in conservative side

$T_{anchor\_factored} := 1.6 \cdot \left(T_{anchor\_applied}\right) = 1.58 \cdot kip$ — max. total Tension load of on one anchor

$N_{tension} := 1$ — number of tension bolt in group,

<u>assuming cracked concrete</u>

<u>the nominal strength of one anchor rod</u>

$N_{sa} := 10.705kip$ — Per Appendix: ESR_1917 Table 3

$\phi_{steel\_tension} := 0.75$ — Per Appendix: ESR_1917 Table 3

$\phi N_{sa} := \phi_{steel\_tension} \cdot N_{sa} = 8.03 \cdot kip$

Project: **Glass guardrail Product Silicone & Anchor**
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concrete breakout strength of anchor in tension

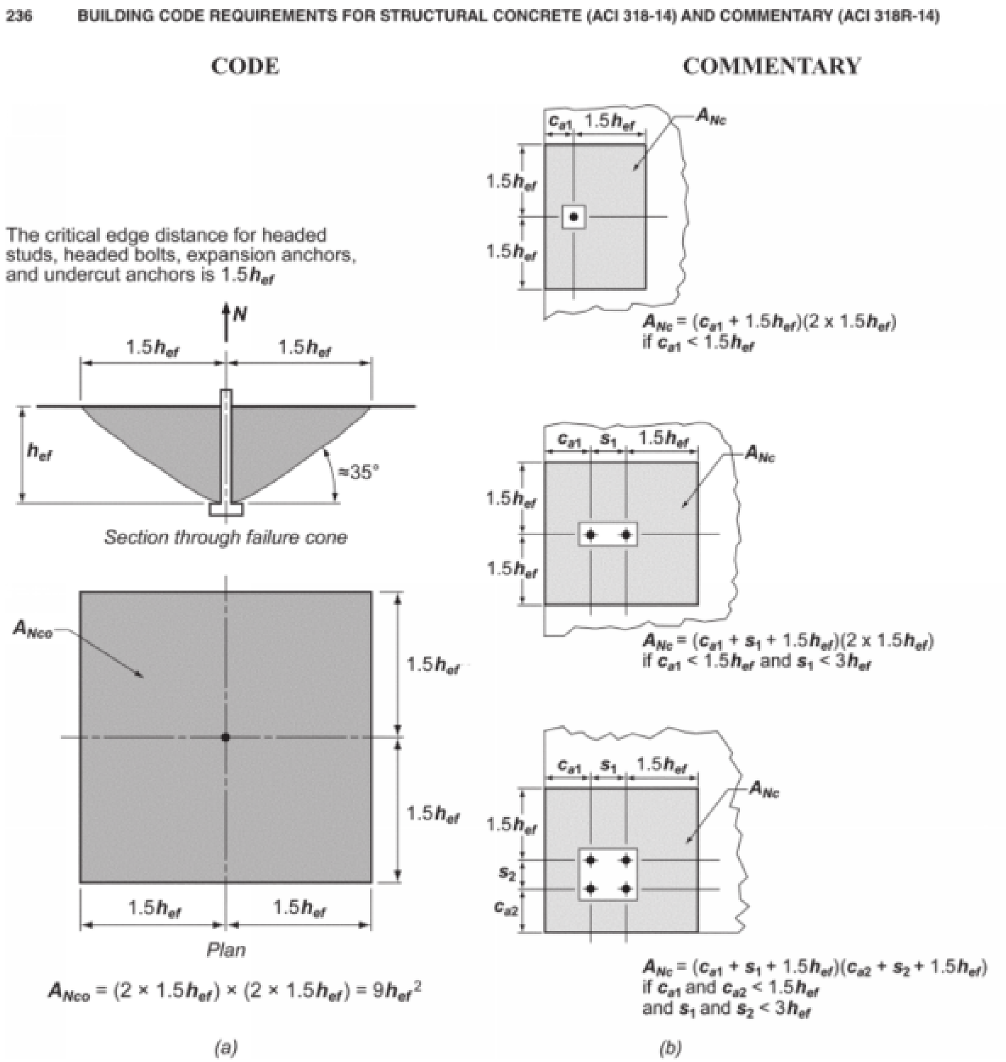

Fig. R17.4.2.1—(a) Calculation of A_{Nco} and (b) calculation of A_{Nc} for single anchors and groups of anchors.

For the definition of varies, see above figure.

$c_{a1} := 2.5in$ bolt edge distance (assumed)

$c_{a2} := 8in$ bolt edge distance (assumed)

$h_{ef} := 3.25in$

$C_{ac1} := 7.25in$

critical distance per ESR-1917 Report, Table 3
for min. 6" thickness concrete slab

$C_{ac} := \min(1.5 \cdot h_{ef}, C_{ac1}) = 4.88 \cdot in$

critical distance

$A_{Nco} := (2 \cdot 1.5 \cdot h_{ef}) \cdot (2 \cdot 1.5 \cdot h_{ef}) = 95.06 \cdot in^2$

$A_{Nc} := \min[6in, (1.5 \cdot h_{ef} + \min(c_{a1}, 1.5 \cdot h_{ef}))] \cdot (\min(c_{a2}, 1.5 \cdot h_{ef}) + 1.5 \cdot h_{ef}) = 58.50 \cdot in^2$

$$\psi_{edN} := \min\left(1, 0.7 + 0.3 \cdot \frac{\min(c_{a1}, c_{a2})}{1.5 \cdot h_{ef}}\right) = 0.85$$

Modification factor for anchor bolt group
edge effect in tension. ACI 318-14 Eq. 17.4.2.4

$\psi_{cN} := 1.0$

Per ESR-1917 table 3

$$\psi_{cpN} := \min\left(1, \max\left(\frac{1.5 \cdot h_{ef}}{C_{ac}}, \frac{c_{a1}}{C_{ac}}\right)\right) = 1.00$$

Modification factor for anchor bolt
group in tension for post-installed anchor
ACI 38-14 Eq. 17.4.2.7a &7b

$k_{cr} := 17$

Per ESR 1917 Table 3

$\lambda := 1.0$

for normal weight concrete

$F_c := 2.5ksi$

$$N_{b1} := k_{cr} \cdot \lambda \cdot \left(\frac{F_c}{1psi}\right)^{0.5} \cdot \left(\frac{h_{ef}}{1in}\right)^{1.5} \cdot 1lbf = 4.98 \cdot kip$$

the basic concrete breakout strength of a single anchor in tension, ACI 318-14 Eq. 17.4.2.2a

$$N_{cb} := \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{edN} \cdot \psi_{cN} \cdot \psi_{cpN} \cdot N_{b1} = 2.62 \cdot kip$$

the nominal concrete breakout strength of anchor group in tension, ACI 318-14 Eq. 17.4.2.1a& 1b

$$\phi_{co\_breakout} := 0.65$$

Per ESR-1917 Table 3

$$\phi N_{cb} := N_{cb} \cdot \phi_{co\_breakout} = 1.70 \cdot kip$$

Concrete Pullout/bond Strength of anchor in tension

$$N_{P\_fc} := 4.915kip = 4.92 \cdot kip$$

Per ESR-1917 Table 3,

$$\phi Pullout := N_{P\_fc} \cdot 0.65 = 3.19 \cdot kip$$

Per ESR-1917 Table 3, 0.65 reduction

Steel Strength of anchor in shear

$$\phi Vsa := 5.495kip \cdot 0.65 = 3.57 \cdot kip$$

Per ESR-1917 Table 3, 0.65 reduction

Concrete breakout Strength of anchor in shear

Reference : ACI 318 -14 Chapter 17

$A_{vco} := 4.5 \cdot c_{a1}^2 = 28.13 \cdot in^2$

ACI 318-14 Eq. 17.5.2.1c

$h_a := 6in = 6.00 \cdot in$

assumed the minimum depth of concrete slab

$C_{a1} := c_{a1} = 2.50 \cdot in$

$A_{vc} := \left(1.5 \cdot C_{a1} + \min\left(c_{a2}, 1.5 \cdot C_{a1}\right)\right) \cdot 1.5 \cdot C_{a1} = 28.13 \cdot in^2$

$$V_{b1} := 7 \cdot \left(\frac{\min\left(d_{anchor} \cdot 8, h_{ef}\right)}{d_{anchor}}\right)^{0.2} \cdot \left(\frac{d_{anchor}}{1in}\right)^{0.5} \cdot \left[\lambda \cdot \left(\frac{F_c}{1psi}\right)^{0.5} \cdot \left(\frac{C_{a1}}{1in}\right)^{1.5}\right] \cdot 1lbf = 1.42 \cdot kip$$

ACI 318-14 Eq. 17.5.2.2a

$$V_{b2} := 9\lambda \cdot \left(\frac{F_c}{1psi}\right)^{0.5} \cdot \left(\frac{C_{a1}}{1in}\right)^{1.5} \cdot (1lbf) = 1.78 \cdot kip$$

ACI 318-14 Eq. 17.5.2.2b

$V_b := \min\left(V_{b1}, V_{b2}\right) = 1.42 \cdot kip$

$e_V := 0.0in$

$$\psi_{ecV} := \frac{1}{1 + \frac{2 \cdot e_V}{3 \cdot C_{a1}}} = 1.00$$

Modification factor for anchor bolt group loaded eccentrically in shear
ACI 318-14 Eq. 17.5.2.5

$\psi_{edV} := 1.0$

Modification factor for anchor bolt group edge effect in shear
ACI 318-14 Eq. 17.5.2.6a for ca2> 1.5Ca1

$\psi_{cV} := 1.0$

Modification factor for anchor bolt group in shear for post-installed anchor
ACI 318-14 item 17.5.2.7

$\psi_{ch} := 1.0$

Modification factor for anchor bolt located in a concrete member where
ha < 1.5ca1, ACI 318-14 item 17.5.2.8

$$V_{cbg} := \frac{A_{vc}}{A_{vco}} \cdot \psi_{ecV} \cdot \psi_{edV} \cdot \psi_{cV} \cdot \psi_{ch} \cdot V_b = 1.42 \cdot kip$$

the nominal concrete breakout strength of anchor group in tension, ACI 318-14 Eq. 17.5.2.1a & 1b.

Concrete pry out Strength of anchor in shear

$K_{cp} := 2.0$

ESR-1917 Table 3

$\phi_{shear\_cr} := 0.70$

$$\phi V_{cpg} := \phi_{shear\_cr} \cdot K_{cp} \cdot N_{cb} = 3.66 \cdot kip$$

$$\phi N_b := \min\left(\phi N_{cb}, \phi N_{sa}, \phi Pullout\right) = 1.70 \cdot kip$$

$$\phi V_n := \min\left(\phi V_{cpg}, \phi Vsa, \phi_{shear\_cr} \cdot V_{cbg}\right) = 1.00 \cdot kip$$

$$ratio_{shear} := \frac{V_{anchor\_factored}}{\phi V_n} = 0.19$$

if Vu is less than 0.2 ϕV_n,,then full strength in tension shall be permitted. no need to check the interaction of tensile and shear forces

$$\frac{T_{anchor\_factored}}{\phi N_b} + \frac{V_{anchor\_factored}}{\phi V_n} = 1.12$$

Note: 1 anchor bolt is in tension and 1 anchor bolt is in shear

$$Tension_{anchor} := \begin{vmatrix} \text{"OK !!"} & \text{if } T_{anchor\_factored} \le \phi N_b \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$Tension_{anchor} = \text{"OK !!"}$

$$Shear_{anchor} := \begin{vmatrix} \text{"OK !!"} & \text{if } V_{anchor\_factored} \le \phi V_n \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$Shear_{anchor} = \text{"OK !!"}$

$$V\_T_{anchor\_check} := \begin{vmatrix} \text{"OK !!"} & \text{if } \frac{T_{anchor\_factored}}{\phi N_b} + \frac{V_{anchor\_factored}}{\phi V_n} \le 1.2 \\ \text{"NG !!"} & \text{otherwise} \end{vmatrix}$$

$V\_T_{anchor\_check} = \text{"OK !!"}$

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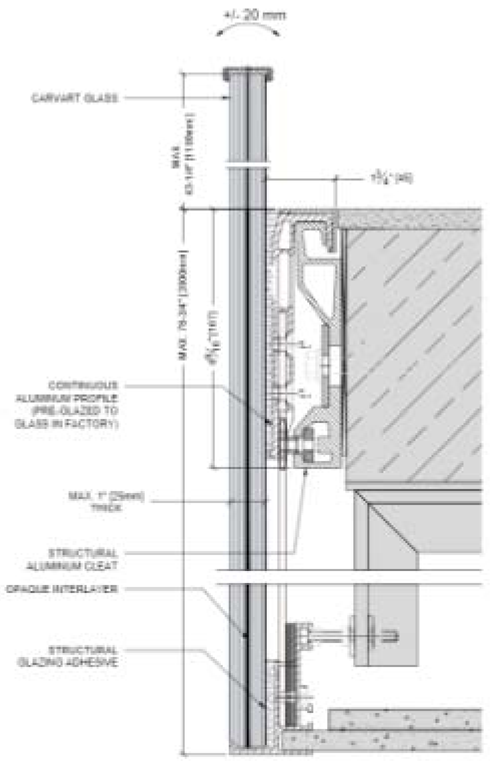
6.0 Design of Concrete Anchor *anchor* *(glassRAILING>PLAN): B. EXTENDED*



B. EXTENDED

Note
1. As a illustrative sample here, HILTI KWIK BOLT TZ (KB-TZ) carbon steel anchor is selected for design.
2. it is contractor engineer's responsibility/libaility to design the anchor. the design here is a recommendation.
3. the lateral concrete acnhor does not carry the dead load of glass panel.

$W_{guardail} := 4ft$ width of guardrail panel

$Spacing_{anchor1} := 16in$ spacing of lateral anchor

$N_{anchor} := floor\left(\frac{W_{guardail}}{Spacing_{anchor1}}\right) = 3.00$ Number of anchor for one glass panel

$Edge_{anchor} := 2.5in$ — minimum edge distance

$LL_{panel} := \max(PLL, ULL \cdot W_{guardail}) = 200.00\,lbf$ — max. live load on one panel

$T_{anchor\_applied} := \dfrac{LL_{panel} \cdot (79in + 43.25in)}{24in \cdot N_{anchor}} = 339.58\,lbf$ — tension load on one anchor

3/8" Dia. anchor bolt with 2.5" embedment

$ESR - 1917$

$d_{anchor} := \dfrac{3}{8} in$ — anchor bolt size

$Embedment_{anchor} := 2in$ — anchor bolt embedment depth

$T_{anchor\_factored} := 1.6 \cdot (T_{anchor\_applied}) = 0.54 \cdot kip$ — max. total Tension load of on one anchor

$N_{tension} := 1$ — number of tension bolt in group,

assuming cracked concrete

the nominal strength of one anchor rod

$N_{sa} := 6.5kip$ — Per Appendix: ESR_1917 Table 3

$\phi_{steel\_tension} := 0.75$ — Per Appendix: ESR_1917 Table 3

$\phi N_{sa} := \phi_{steel\_tension} \cdot N_{sa} = 4.88 \cdot kip$

concrete breakout strength of anchor in tension

$c_{a1} := 2.5in$ — bolt edge distance (assumed)

$c_{a2} := 8in$ — bolt edge distance (assumed)

$h_{ef} := 2in$

$C_{ac1} := 4in$ — critical distance per ESR-1917 Report, Table 3 for min. 5" thickness concrete slab

$C_{ac} := \min(1.5 \cdot h_{ef}, C_{ac1}) = 3.00 \cdot in$ — critical distance

$A_{Nco} := (2 \cdot 1.5 \cdot h_{ef}) \cdot (2 \cdot 1.5 \cdot h_{ef}) = 36.00 \cdot in^2$

$A_{Nc} := \min[(1.5 \cdot h_{ef} + \min(c_{a1}, 1.5 \cdot h_{ef})), 5in] \cdot (\min(c_{a2}, 1.5 \cdot h_{ef}) + 1.5 \cdot h_{ef}) = 30.00 \cdot in^2$

$$\psi_{edN} := \min\left(1, 0.7 + 0.3 \cdot \frac{\min(c_{a1}, c_{a2})}{1.5 \cdot h_{ef}}\right) = 0.95$$

Modification factor for anchor bolt group edge effect in tension. ACI 318-14 Eq. 17.4.2.4

$\psi_{cN} := 1.0$ — Per ESR-1917 table 3

$$\psi_{cpN} := \min\left(1, \max\left(\frac{1.5 \cdot h_{ef}}{C_{ac}}, \frac{c_{a1}}{C_{ac}}\right)\right) = 1.00$$

Modification factor for anchor bolt group in tension for post-installed anchor ACI 38-14 Eq. 17.4.2.7a &7b

$k_{cr} := 17$ Per ESR 1917 Table 3

$\lambda := 1.0$ for normal weight concrete

$F_c := 2.5ksi$

$$N_{b1} := k_{cr} \cdot \lambda \cdot \left(\frac{F_c}{1psi}\right)^{0.5} \cdot \left(\frac{h_{ef}}{1in}\right)^{1.5} \cdot 1lbf = 2.40 \cdot kip$$

the basic concrete breakout strength of a single anchor in tension, ACI 318-14 Eq. 17.4.2.2a

$$N_{cb} := \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{edN} \cdot \psi_{cN} \cdot \psi_{cpN} \cdot N_{b1} = 1.90 \cdot kip$$

the nominal concrete breakout strength of anchor group in tension, ACI 318-14 Eq. 17.4.2.1a& 1b

$\phi_{co\_breakout} := 0.65$ Per ESR-1917 Table 3

$\phi N_{cb} := N_{cb} \cdot \phi_{co\_breakout} = 1.24 \cdot kip$

Concrete Pullout/bond Strength of anchor in tension

$N_{P\_fc} := 2.27kip = 2.27 \cdot kip$ Per ESR-1917 Table 3,

$\phi Pullout := N_{P\_fc} \cdot 0.65 = 1.48 \cdot kip$ Per ESR-1917 Table 3, 0.65 reduction

$\phi N_b := \min(\phi N_{cb}, \phi N_{sa}, \phi Pullout) = 1.24 \cdot kip$

Note: 1 anchor bolt is in tension

$$Tension_{anchor} := \begin{cases} \text{"OK !!"} & \text{if } T_{anchor\_factored} \le \phi N_b \\ \text{"NG !!"} & \text{otherwise} \end{cases}$$

$Tension_{anchor} = \text{"OK !!"}$