Blast Window Analyses

Subject: BR 7500 Series Blast Resistant Awning Window

ATI Report 57403.01-122-34

Rendered to:

International Aluminum Corporation
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Scope

Architectural Testing, Inc. was contracted by International Aluminum Corporation to perform engineering analyses of their BR 7500 Series blast resistant window. The analysis includes generic installation details. The analysis was conducted to show compliance to the requirements of Minimum Antiterrorism Standards for Buildings – UFC 4-010-01.

Based on the installed window sizes and the procedures of UFC 4-010-01, linear-elastic static structural analyses assuming static pressure loads of 4.4 psi and 10.8 psi were performed for the window glazing parts and window anchorage. And, linear-elastic static structural analyses assuming a static pressure load of 1.0 psi were performed for the window frame parts.

Standards and references utilized in this project include:

Minimum Antiterrorism Standards for Buildings – UFC 4-010-01 United States Department of Defense, 8 October 2003.

Aluminum Design Manual 2000. The Aluminum Association, Inc., 2000.

Metal Curtain Wall Fasteners – AAMA TIR-A9-1991. American Architectural Manufacturers Association.

Analyses

Glazing System

The window system provides clearance for 1" thick insulated glass. (Drawing USA-2872 Sheet 3). The minimum requirement for insulated glass is a 5/16" thick laminated inner lite constructed from two 1/8" thick pieces of annealed glass with a 0.030" thick PVB interlayer. The glass specified for the window system (Drawing USA-2872 Sheet 1, Item 6) is in compliance with UFC 4-010-01 Section B-3.1.1.

The vent is exterior glazed against an integral leg of the vent frame. The glass bite is approximately 7/8" and structural silicone sealant is used (Drawing USA-2872 Sheet 1, Item 8). The glazing system is in compliance with UFC 4-010-01 Section B-3.1.2.2.

Depending on the sizes of the installed windows, the glazing stop must be capable of resisting a 4.4 psi or 10.8 psi static pressure load applied to the surface of the glazing in accordance with UFC 4-010-01 Section B-3.1.2.3. Windows are to be exterior glazed and, there for, rely on the sash frame leg to restrain the glazing. Analysis considering the shear and bending stresses developed on the sash frame leg is presented on Page 5 and Page 6. The calculated stresses are above the allowable values established by UFC 4-010-01 for windows less than 10.8 ft^2. The sash frame can be made compliant with the requirements if the sash and window frame is thickened to 5/32", the sash and window alloy is changed to 6061-T6 or 6063-T6 or the maximum window height is limited to 25".

Frame Member Design

A stress and deflection analysis was conducted for the structural members of the windows. The window jamb, sill and head sections anchored to the building substrate are analyzed as simple supported beams over multiple supports.

The stress and deflection analysis is presented on Page 7 and Page 8. The results of the calculations reveal that the window frame stresses are below the allowed value (0.2% Offset Yield Stress per UFC 4-010-01 Section B-3.1.2.1) for the installed window sizes. Also, calculated deflections were within the $\ell/60$ inches requirement for the spans analyzed.

Installation

Based on the sizes of the installed windows, anchorages must be capable of resisting a 4.4 psi or a 10.8 psi static pressure load applied over the surface of the window in accordance with UFC 4-010-01 Section B-3.1.2.3. First, individual anchor load capacities are established based on bearing stresses at the window frame, connection shear between the window frame and the substrate or shear stress of the anchor. Then, the individual anchor load capacities and application of the UFC principals are used to determine a general anchor spacing for the windows. Calculations are presented on Page 9 through Page 11.

Calculations are performed for two typical anchors (#12-14 and #10-16 screws) and four common substrates (0.063" thick, 0.080" thick, 0.093" thick and 0.125" thick aluminum curtain wall members). Results are summarized in the following tables.

#10-16 Screw SAE Grade 5				
Substrate Thickness (inch)	**Anchor Capacity (lb)**	**Comment**	**Required Spacing**	
			4.4 psi	**10.8 psi**
0.062	621	Limited by connection shear	12	5
0.080	910	Limited by connection shear	16	8
0.093	1,065	Limited by bearing stress	16	10
0.125	1,065	Limited by bearing stress	16	10

#12-14 Screw SAE Grade 5				
Substrate Thickness (inch)	**Anchor Capacity (lb)**	**Comment**	**Required Spacing**	
			4.4 psi	**10.8 psi**
0.062	662	Limited by connection shear	14	6
0.080	971	Limited by connection shear	16	9
0.093	1,211	Limited by bearing stress	16	12
0.125	1,211	Limited by bearing stress	16	12

Spacing maximum of 16" is required by structural analysis of the frame parts.

Reference Drawings (attached)

Dimensional Layout for DoD BR7500 Window. Sheets 1 - 3, International Aluminum Corporation.

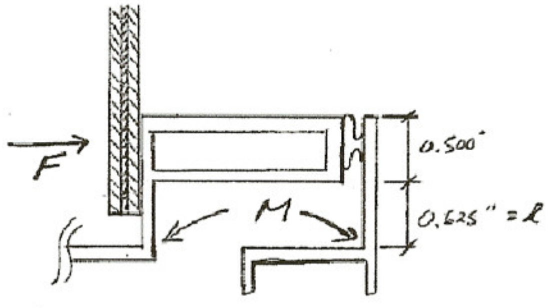
7500 VENT, Die No. H-60982 A1, International Aluminum Corporation.

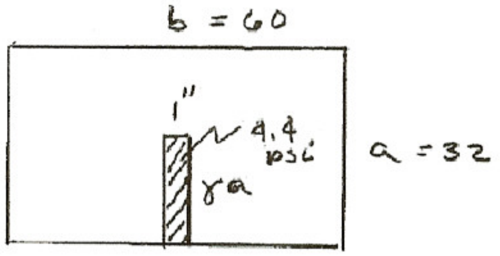
7500 SILL/HEAD, Die No. H-60980 A1, International Aluminum Corporation.

7500 JAMB, Die No. H-60981 A1, International Aluminum Corporation.

CORNER ANGLE, Die No. H-30958 C4, International Aluminum Corporation.

CHECK GLAZING STOP





PERFORM BENDING AND SHEAR ANALYSIS PER UNIT LENGTH OF FRAME

$F = p a \gamma$ $\quad b/a = 60/32 = 1.875 \quad \gamma = 0.501$

$F = (4.4)(32)(0.501)$

$F = 70.5$ lb/inch

$M = M_{TOT}/2 = Fl/2 = (70.5)(0.625)/2 = 22.0$ in-lb/in

$S = t^2/6 = (0.125)^2/6 = 0.0026$ in³/inch

$A = t/1 = 0.125$ in²/inch

$\sigma = M/S = 22.0/0.0026 = 8{,}461$ psi

$\tau = F/A = 70.5/0.125 \quad 564$ psi

$\frac{8{,}461}{16{,}000} + \frac{564}{16{,}000} = 0.56 \le 1.0$ OK

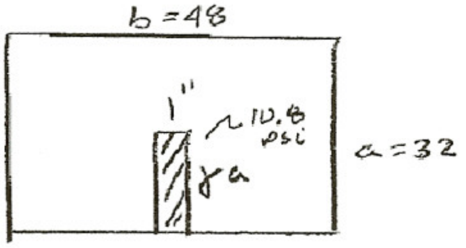
GLAZING STOP OK FOR 4.4 psi

MAX SIZE FOR 10.8 psi

$10.8\ ft^2 = 1555\ in^2$

$1{,}555/32 = 48.6$

48 × 32 IS LARGEST WINDOW WITH 10.8 psi GLAZING LOAD



$F = p a \gamma \qquad b/a = 48/32 = 1.5 \qquad \gamma = 0.485$

$F = (10.8)(32)(0.485) = 167.6$ lb/inch

$M = M_{TOT}/2 = (167.6)(0.625)/2 = 52.4$ lb-in/in

$\sigma = M/s = 52.4/0.0026 = 20{,}153$ psi $> 16{,}000$

STRESSES TOO HIGH

OPTION 1 USE 6061-T6 ALLOY $F_{TY} = 35{,}000$ psi
6063-T6 ALLOY $F_{TY} = 25{,}000$ psi

OPTION 2 INCREASE THICKNESS
to $\frac{20{,}153}{16{,}000} 0.125 = 0.157'' \approx 5/32$

OPTION 3 LIMIT a to $\frac{16{,}000}{20{,}153} 32 = 25''$

CHECK FRAME STRESS + DEFLECTION 60 X 32 WINDOW

$I_{SASH} = 0.407 \text{ in}^4$ ✓ $c_{SASH} = 1.536 \text{ in}$ ✓

$I_{JAMB} = 0.055 \text{ in}^4$ ✓ $c_{JAMB} = 0.833 \text{ in}$ ✓

$I_{HEAD} = 0.064 \text{ in}^4$ ✓ $c_{HEAD} = 0.079 \text{ in}$

ASSUME FRAME + SASH BEHAVE NON-COMPOSITELY

JAMB STRESS

$I_{TOT} = 0.407 + 0.055 = 0.462 \text{ in}^4$

$c = 1.536 \text{ in}$

ASSUME FASTENER SPACING OF 16" ON CENTER MAXIMUM

$\sigma = \frac{Mc}{I} = \frac{(DPA\ell)c}{8I} = \frac{(1 \text{ psi})(30)(32)(16)(1.536)}{8(0.462)}$ CONSERVATIVE

$\sigma = 6,383 \text{ psi} < 15,968 \text{ psi}$ OK

JAMB DEFLECTION

$\Delta = \frac{5}{384}\frac{DPA\ell^3}{EI} = \frac{5}{384}\frac{(1 \text{ psi})(30)(32)(16)^3}{(10,100,000)(0.462)}$

$\Delta = 0.011 \text{ in}$ ✓ $< \ell/60 = 16/60 = 0.267 \text{ in}$ OK

HEAD STRESS

$I_{TOT} = 0.407 + 0.064 = 0.471 \text{ in}^4$

$c = 1.536 \text{ in}$

$\sigma = \dfrac{(1 psi)(1/16)(60)(16)(1.536)}{8(0.471)}$

$\sigma = 6{,}261 \text{ psi} < 15{,}968 \text{ psi}$ OK ✓

JAMB DEFLECTION

$\Delta = \dfrac{5}{384} \dfrac{(1 psi)(30 \times 32)(16)^2}{(10{,}100{,}000)(0.471)}$

$\Delta = 0.011 \text{ in} < 0.267 \text{ in}$ OK

ANCHOR CAPACITIES

#12-14 SAE GRADE 5

$D = 0.216$ in

$A_{ROOT} = 0.0214$ in^2

$F_u = 120{,}000$ psi

$l =$ UNSHIMMED LENGTH ≈ 3/8 = 0.375 in

$l/D = 0.375/0.216 = 1.7 < 3$ SCREW IS IN SHEAR

BEARING AT FRAME

$V_{MAX} = (D)(t)(F_B)(1.95)$

$= (0.216)(0.125)(23{,}000)(1.95)$

$= 1{,}211$ lb

CONNECTION SHEAR $(t_2 \leq t_1)$

$P_{NS} = 4.2(t_2^3 D)^{1/2} F_{TU2}$ $F_{TU2} = 22{,}000$ psi

t_2	P_{NS}	
0.062	662 lb	< 1211 lb
0.080	971 lb	< 1211 lb
0.093	1,217 lb	> 1211 lb
0.125	1,898 lb	> 1211 lb

SHEAR OF SCREW

$\tau = (1211)/0.0214 = 56{,}588$ psi OK

#10 - 16 SAE GRADE 5

$D = 0.190$ in

$A_R = 0.0152\ in^2$

$\ell = 0.375$

$\ell / D = 0.375 / 0.190 = 1.97 < 3$ SHEAR

BEARING AT FRAME

$V_{max} = (0.190)(0.125)(23,000)(1.95)$
$= 1,065$ lb

CONNECTION SHEAR

t_2	P_{NS}	
0.062	621 lb	< 1065
0.080	910 lb	< 1065
0.093	1,141 lb	> 1065
0.125	1,780 lb	> 1065

SHEAR OF SCREW

$\tau = 1065 / 0.0152 = 70,066$ psi OK

SUMMARY

t_2	V_{max} #10	#12
0.062	621	662
0.080	910	971
0.093	1,065	1,211
0.125	1,065	1,211

ANCHOR SPACING

4.4 psi WINDOWS ($A > 10.8\ ft^2$)

$F_{MAX} = (4.4)(32)(60) = 8{,}448\ lb$

\# SCREWS = F_{MAX} / V_{MAX} (ROUND UP)

SPACING = PERIMETER / # SCREWS ($< 16''$)

t_2	#10	#12
0.062	12"	14"
0.080	16"	16"
0.093	16"	16"
0.125	16"	16"

10.8 psi WINDOWS ($A < 10.8\ ft^2$)

$F_{MAX} = (10.8)(10.8)(144) = 16{,}796\ lb$

MAX PERIM = $(32+48)(2) = 160\ in$

t_2	#10	#12
0.062	5"	6"
0.080	8"	9"
0.093	10"	12"
0.125	10"	12"

Revision Log

Rev. #	Date	Page(s)	Revision(s)
0	08/15/05	All	Original report issue