Blast Window Analyses

Subject: BR 7500 Series Blast Resistant Awning Window

 ATI Report 57403.01-122-34

Rendered to:

International Aluminum Corporation
767 Monterey Pass Road
Monterey Park, California 91754

Prepared by:

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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:


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 ft². 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 \( \frac{f}{60} \) 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.

<table>
<thead>
<tr>
<th>Substrate Thickness (inch)</th>
<th>Anchor Capacity (lb)</th>
<th>Comment</th>
<th>Required Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.4 psi</td>
</tr>
<tr>
<td>0.062</td>
<td>621</td>
<td>Limited by connection shear</td>
<td>12</td>
</tr>
<tr>
<td>0.080</td>
<td>910</td>
<td>Limited by connection shear</td>
<td>16</td>
</tr>
<tr>
<td>0.093</td>
<td>1,065</td>
<td>Limited by bearing stress</td>
<td>16</td>
</tr>
<tr>
<td>0.125</td>
<td>1,065</td>
<td>Limited by bearing stress</td>
<td>16</td>
</tr>
</tbody>
</table>

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<th>Required Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.4 psi</td>
</tr>
<tr>
<td>0.062</td>
<td>662</td>
<td>Limited by connection shear</td>
<td>14</td>
</tr>
<tr>
<td>0.080</td>
<td>971</td>
<td>Limited by connection shear</td>
<td>16</td>
</tr>
<tr>
<td>0.093</td>
<td>1,211</td>
<td>Limited by bearing stress</td>
<td>16</td>
</tr>
<tr>
<td>0.125</td>
<td>1,211</td>
<td>Limited by bearing stress</td>
<td>16</td>
</tr>
</tbody>
</table>

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.


CHECK GLAZING STOP

**Perform Bending and Shear Analysis Per Unit Length of Frame**

\[
F = P \alpha \gamma \quad \text{where} \quad b/a = 60/32 = 1.875 \quad \gamma = 0.501
\]

\[
F = (4.4)(32)(0.501) = 70.5 \text{ in/lb}
\]

\[
M = M_{tot}/2 = FL/2 = (70.5)(0.625)/2 = 22.0 \text{ in-lb/in}
\]

\[
S = \frac{\gamma b^2}{6} = (0.125)(6) = 0.076 \text{ in}^2/\text{in}
\]

\[
A = 4/1 = 0.125 \text{ in}^2/\text{in}
\]

\[
\sigma = \frac{M_S}{A} = \frac{22.0}{0.125} = 176 \text{ psi}
\]

\[
\varepsilon = \frac{F_A}{E_A} = \frac{70.5}{0.125} = 564 \text{ psi}
\]

\[
\frac{8461}{16000} + \frac{564}{16000} = 0.56 < 1.0 \quad \text{OK}
\]

**Glazing Stop OK for 4.4 psi**
Max Size for 10.8 psi

\[ 10.8 \frac{\text{in}^2}{\text{in}^2} = 1555 \text{ in}^2 \]
\[ \frac{1555}{32} \approx 48.6 \]

48 x 32 is largest window with 10.8 psi glazing load

\[ b = 48 \]
\[ a = 32 \]

\[ F = \frac{p a}{b} = \frac{48}{32} = 1.5 \]
\[ \gamma = 0.485 \]
\[ F = (10.8)(32)(0.485) = 147.4 \text{ in/lb} \]
\[ M = M_{\text{max}}/2 = (147.4)(0.625)/2 = 52.4 \text{ in/ft} \]
\[ \gamma = M/s = 52.4/0.0025 = 20,153 \text{ psi} > 14,000 \]

Stresses too high

**Option 1**
Use 6061-T6 Alloy \( F_{\text{ty}} = 35,000 \text{ psi} \)
Use 6063-T6 Alloy \( F_{\text{ty}} = 25,000 \text{ psi} \)

**Option 2**
Increase thickness to \( \frac{20,153}{16,000} = 0.125 = 0.157'' \) & 5/32

**Option 3**
Limit \( a \) to \( \frac{16,000}{20,153} \times 32 = 25'' \)
Check Frame Stress + Deflection 60 x 32 Window

\[ I_{\text{Sash}} = 0.407 \text{ in}^4 \checkmark \quad C_{\text{Sash}} = 1.536 \text{ in} \checkmark \]

\[ I_{\text{Frame}} = 0.055 \text{ in}^4 \checkmark \quad C_{\text{Frame}} = 0.833 \text{ in} \checkmark \]

\[ I_{\text{Jamb}} = 0.064 \text{ in}^4 \checkmark \quad C_{\text{Jamb}} = 0.079 \text{ in} \]

Assume Frame + Sash Behave Non-Compositely

Jamb Stress

\[ I_{\text{Tot}} = 0.407 + 0.055 + 0.462 \text{ in}^4 \]
\[ C = 1.536 \text{ in} \]

Assume fastener spacing of 16" on center maximum

\[ \sigma = \frac{Mc}{I} = \frac{(0.048)(c)}{8} \geq \left(1.933 \right) \left(30 \right) \left(32 \right) \left(1.536 \right) \]

\[ \sigma = 63.83 \text{ psi} \leq 15,968 \text{ psi} \text{ OK} \]

Jamb Deflection

\[ \Delta = \frac{5}{384} \frac{GPR^3}{E} = \frac{5}{384} \frac{(106)(30)(32)(1.536)^3}{(0.462)} \]

\[ \Delta = 0.011 \text{ in} \leq \frac{60}{60} = \frac{1}{60} = 0.067 \text{ in} \text{ OK} \]
**Head Stress**

\[ I_{cyc} = 0.407 + 0.064 = 0.471 \text{ in}^4 \]
\[ c = 0.536 \text{ in} \]
\[ \sigma = \frac{(100)(1/4)(60)(14)(1.536)}{8(0.471)} \]

\[ \sigma = 6261 \text{ psi} < 15968 \text{ psi}; \text{ OK} \]

**Jam Deflection**

\[ \Delta = \frac{5}{384} \frac{(12)(30 \times 32)(14)^3}{(14,109,000)(0.471)} \]

\[ \Delta = 0.011 \text{ in} < 0.267 \text{ in}; \text{ OK} \]
ANCHOR CAPACITIES

# 12-14 SAE GRADE 5

\[
D = 0.214 \text{ in} \\
A_{\text{root}} = 0.0214 \text{ in}^2 \\
F_u = 120,000 \text{ psi} \\
L = \text{UNSHIMMED LENGTH} = 3/8 = 0.375 \text{ in} \\
L/D = 0.375/0.214 = 1.7 < 3 \quad \underline{\text{Screw IS IN SHEAR}}
\]

BEARING AT FRAME

\[
V_{\text{max}} = (D)(t_2)(F_u)(1.95) \\
= (0.214)(0.125)(23,000)(1.95) \\
= 1.214 \text{ in}
\]

CONNECTION SHEAR \quad (t_2 \leq t_1)

\[
F_{n_s} = 4.2 \left( \frac{L^3}{D} \right) F_{n_2} \\
F_{n_2} = 22,000 \text{ psi}
\]

<table>
<thead>
<tr>
<th>(t_2)</th>
<th>(F_{n_s})</th>
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<tbody>
<tr>
<td>0.062</td>
<td>0.062 16</td>
</tr>
<tr>
<td>0.080</td>
<td>0.071 16</td>
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<tr>
<td>0.093</td>
<td>1.217 16</td>
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<tr>
<td>0.125</td>
<td>1.898 16</td>
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</tbody>
</table>

Shear of Screw

\[
t = \frac{(1211)}{0.0214} = 56,588 \text{ psi} \quad \underline{012}
\]
\#10-14 SAE Grade 5

D = 0.190 in
\(A_r = 0.0152 \text{ in}^2\)
\(l = 0.375\)
\(l/D = 0.375/0.190 = 1.97 < 3\)

Shear at Frame

\[V_{\text{max}} = (0.190)(0.125)(23,000)(1.95)\]
\[= 4,065\text{ lb} \]

Connection Shear

<table>
<thead>
<tr>
<th>(c_2)</th>
<th>(P_{\text{lbs}})</th>
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</thead>
<tbody>
<tr>
<td>0.062</td>
<td>621 16</td>
</tr>
<tr>
<td>0.080</td>
<td>910 16</td>
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<tr>
<td>0.093</td>
<td>1,141 16</td>
</tr>
<tr>
<td>0.125</td>
<td>1,780 16</td>
</tr>
</tbody>
</table>

Shear of Screw

\[c = 1065/0.0152 = 70,066 \text{ psi OK}\]

Summary

<table>
<thead>
<tr>
<th>(c_2)</th>
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<th>#12</th>
</tr>
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<tbody>
<tr>
<td>0.062</td>
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</tr>
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<td>0.093</td>
<td>1,045</td>
<td>1,211</td>
</tr>
<tr>
<td>0.125</td>
<td>1,045</td>
<td>1,211</td>
</tr>
</tbody>
</table>
# Anchor Spacing

4.4 psi Windows  \((A > 10.8 \text{ ft}^2)\)

\[ F_{\text{max}} = (4.4)(32)(60) = 8,448 \text{ lb} \]

\# Screws = \( \frac{F_{\text{max}}}{V_{\text{max}}} \) (Round Up)

Spacing = \( \frac{\text{Perimeter}}{\# \text{ Screws}} \) (<16”)

<table>
<thead>
<tr>
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<th># 10</th>
<th># 12</th>
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</thead>
<tbody>
<tr>
<td>0.062</td>
<td>12”</td>
<td>14”</td>
</tr>
<tr>
<td>0.080</td>
<td>16”</td>
<td>16”</td>
</tr>
<tr>
<td>0.093</td>
<td>16”</td>
<td>16”</td>
</tr>
<tr>
<td>0.125</td>
<td>16”</td>
<td>16”</td>
</tr>
</tbody>
</table>

10.8 psi Windows  \((A < 10.8 \text{ ft}^2)\)

\[ F_{\text{max}} = (10.8)(10.8)(144) = 16,796 \text{ lb} \]

\[ V_{\text{max}} = \frac{52+48}{2} = 160 \text{ in} \]

<table>
<thead>
<tr>
<th>62</th>
<th># 10</th>
<th># 12</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5”</td>
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<tr>
<td>0.080</td>
<td>8”</td>
<td>9”</td>
</tr>
<tr>
<td>0.093</td>
<td>10”</td>
<td>12”</td>
</tr>
<tr>
<td>0.125</td>
<td>10”</td>
<td>12”</td>
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