Florida Structural Engineers

South Florida Chapter
January 8, 2008
Miami Lakes, Florida

Aluminum Association of Florida, Inc.
Joe Belcher ~ David Miller
AAF Code Involvement:
Historical Perspective

- 1998: commits to participate FBC
- 1999: commits to wind tunnel testing
- 2001: submits Table 2002.4 load table and related code provisions
- 2004: AAF Guide adopted into FBC
- 2005/2006: AAF sponsors and moderates Consensus Engineering Design Conferences
- 2006/2007: updates/revises prescriptive guide

(AAF Guide to Aluminum Construction in High Wind Areas)
Wind Tunnel Testing Program 1999

Consultants:

Timothy Reinhold, Ph.D., P.E.
Charles Everly, P.E.
(ASCE7 Windload Committee)

Phase 1 at Virginia Tech (screen drag force)
Phase 2 at Clemson (scale models)
Boundary Layer Wind Tunnel - Clemson
Test bed & scale model
High Frequency Force Balance
Attached Shed Screen Roof Enclosure

- an alternative design methodology for typical aluminum patio projects of lesser complexity (not a standard)
- developed beginning in 2001
- adopted into FBC 2004
- implemented October 2005
- Updated 2006/2007

AREAS OF DISAGREEMENT

• Magnitude of pressures
• Application of pressures
• Behavior/Properties of Extrusions
• Behavior of the Frame
Engineering Consensus Conferences 2005-2006:

1. Establishes interpretation on Table 2002.4 and submits code change to simplify and clarify
2. Establishes simultaneous loading
3. Explores proper use of the ADM in evaluating extrusion capabilities
<table>
<thead>
<tr>
<th>Surface</th>
<th>Exposure Category (B or C)</th>
<th>Design Pressure (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Basic Wind Speed (mph)</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Horizontal Pressure on Windward Surfaces</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Horizontal Pressure on Leeward Surfaces</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Vertical Pressure on Screen Surfaces</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Vertical Pressure on Solid Surfaces</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>
Table 2002.4 Notes:

1. Pressures include importance factors determined in accordance with Table 1604.5.
2. Pressures apply to enclosures with a mean enclosure roof height of 30 ft (10 m) or less. For other heights, multiply the pressures in this table by the factors in Table 2002.4A.
3. Apply horizontal pressures to the area of the enclosure projected on a vertical plane normal to the assumed wind direction, simultaneously inward on the windward side and outward on the leeward side.
4. Apply vertical pressures upward and downward to the area of the enclosure projected on a horizontal plane.
5. **Apply horizontal pressures simultaneously with vertical pressures.**
6. Table pressures are MWFRS Loads. The design of solid roof panels and their attachments shall be based on component and cladding loads for enclosed or partially enclosed structures as appropriate.
7. Table pressures apply for all screen densities up to 20 x 20 x 0.013” mesh. For greater densities use pressures for enclosed buildings.
8. Table pressures may be interpolated using ASCE7 methodology.
HVHZ Design Pressures ASCE7
provision 6.5.15
(Design Wind Loads on Other Structures)

\[ F = q_z \cdot G \cdot C_f \cdot A_f \]  
(Equation 6-28)

where \( q_z \) derived from Equation 6-15 (Velocity Pressure):

\[ q_z = 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 \cdot I \]

where: \( I = 0.77 \) (Category I)
- \( K_z = 0.85 \) (Exposure C Height 0 – 15 ft)
- \( K_{zt} = 1 \) (Topographical Factor)
- \( K_d = 0.85 \) (Directionality Factor)
- \( V = \) wind speed (140 or 146)
for \( V = 140 \) \( q_z = 27.9 \) psf;
where \( V = 146, q_z = 30.4 \) psf

\[
F = q_z \cdot G \cdot C_f \cdot A_f
\]

where Gust Factor effect \( G = 0.85 \), and \( C_f = 1.5 \) from Figure 6-22 (Force Coefficients for Open Signs & Lattice Frameworks)

BUT, let’s change \( F \) to \( P_{\text{Screen}} \) by substituting the ratio of solid area to gross area
$$P_{Screen} = q_z \cdot G \cdot C_f \cdot \frac{A_{solid}}{A_{gross}}$$

Typical screen mesh for screen enclosures has a wire or thread diameter ($\varnothing$) of 0.013 in. for 20/20 mesh screen, density is: 45% solid, 55% Open; and for 18/14 mesh 37% solid, 63% Open

$P_{Screen}$ for 140 mph is 16.0 psf, and $P_{Screen}$ for 146 mph is 17.4 psf
These values must be adjusted for roof and wall factors according to FBC 1622, 0.7 and 1.3 respectively.

<table>
<thead>
<tr>
<th>WIND VELOCITY ZONE</th>
<th>140</th>
<th>146</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_z$</td>
<td>27.9</td>
<td>30.4</td>
</tr>
<tr>
<td>20/20 Mesh</td>
<td>16.0</td>
<td>17.4</td>
</tr>
<tr>
<td>Walls</td>
<td>20.8</td>
<td>22.6</td>
</tr>
<tr>
<td>Roof</td>
<td>11.2</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Comparative Values from Table 2002.4

| Windward         | 24.9| 27.0|
| Leeward          | 19.8| 21.8|
| Vertical         | 6.9 | 7.4|
Applying Pressures to a Typical Mansard Frame (in 140 mph HVHZ)

Frame Dimensions:
Mansard Frame Spacing = 6 ft
Wall Height (Eave Height) = 9 ft
Rise: 3 ft (Height Overall = 12 ft)
Beam Span = 24 ft
Beam Stitching: 20 inches O.C.
Assumptions: Simple Supports
Post / Beam Connection pinned
HVHZ Roof Beam Loading

Beam Load: Spacing (6 ft) X Pressure (11.2 psf)
HVHZ Wall Loading

Post Load: Spacing (6 ft) X Pressure (20.8 psf)
Table 2002.4 Windward Pressure

Horizontal Windward Load:
Spacing (6 ft) X Pressure (24.9 psf)
Horizontal Leeward Load:
Spacing (6 ft) X Pressure (19.8 psf)
Table 2002.4 Vertical Pressure

Vertical Load:
Spacing (6 ft) X Pressure (6.9 psf)
Beam Moment ~ HVHZ Roof Only
Beam Moment ~ HVHZ Combined Roof & Wall Pressures
Table 2002.4 Simultaneous Loading ~ Applied Beam Moment

<table>
<thead>
<tr>
<th>Loading Event</th>
<th>Applied Beam Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1482 lb</td>
<td>-394 lb</td>
</tr>
<tr>
<td>-673 lb</td>
<td>-67.3 K-in</td>
</tr>
<tr>
<td>18.2 K-in</td>
<td>-60.1 K-in</td>
</tr>
<tr>
<td>-72.1 K-in</td>
<td></td>
</tr>
<tr>
<td>(Bending / Axial Compression)</td>
<td>$M_z$ (kip-in)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>HVHZ load (roof only)</td>
<td>54.3</td>
</tr>
<tr>
<td>HVHZ (combined loading)</td>
<td>71.2</td>
</tr>
<tr>
<td>Table 2002.4 (simultaneous loading)</td>
<td>72.1</td>
</tr>
</tbody>
</table>

Interaction Ratios for 2X10 SMB:

HVHZ:
- Applied: $71.2 + 0.414 = 0.669$
- Allowable: $114.4 + 8.76$

Table 2002.4
- Applied: $72.1 + 1.125 = 0.758$
- Allowable: $114.4 + 8.76$
Interaction Ratios for 2X9 (0.82” X 0.306”) SMB:

<table>
<thead>
<tr>
<th></th>
<th>$M_z$</th>
<th>$F_x$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied:</td>
<td>71.2</td>
<td>+</td>
<td>0.414</td>
</tr>
<tr>
<td>Allowable:</td>
<td>82.9</td>
<td></td>
<td>6.72</td>
</tr>
</tbody>
</table>

Table 2002.4

<table>
<thead>
<tr>
<th></th>
<th>$M_z$</th>
<th>$F_x$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied:</td>
<td>72.1</td>
<td>+</td>
<td>1.125</td>
</tr>
<tr>
<td>Allowable:</td>
<td>82.9</td>
<td></td>
<td>6.72</td>
</tr>
</tbody>
</table>
Compact Sections [Lumber / Steel]

SYP #2
2X6
Sx = 7.56
Fb = 1.25 ksi

A36 Mild Steel
W 6X15
Sx = 9.72
Fb = 22 ksi
Minimum Mechanical Properties for Alloy 6063-T6

\[ F_{tu} = 30 \text{ ksi} \quad n_u = 1.95 \]
\[ F_{ty} = 25 \text{ ksi} \quad n_y = 1.65 \]

ADM 3.4.2 Tension in Extreme Fibers of Beams
For Flat elements In Uniform Tension
is the lesser of:

\[ F = \frac{F_{tu}}{k_t \cdot n_u} \quad (k_t = 1.0) \quad F = \frac{F_{ty}}{n_y} \]

\[ F = 15.2 \text{ ksi} \]
Aluminum Self-Mating Beam Sections

Wall Thicknesses:
- 2X5 SMB: Web: 0.050” X Flange: 0.116”
- 2X8 SMB: Web: 0.072” X Flange: 0.224”
- 2X9 SMB: Web: 0.082” X Flange: 0.306”
- 2X10 SMB: Web: 0.092” X Flange: 0.374”
ADM Requirements for Major Axis Bending Thin-walled Self-Mating Sections

- **Tension** (3.4.2)

- **Compression**
  1. **Member buckling** (3.4.14)
  2. **Member halves buckling between stitch screws** (3.4.11)
  3. **Local component buckling** *(may take weighted average)*
     - Web (3.4.18)
     - Flange (3.4.15)
Axial compressive strength is the least of:

- Member buckling strength $F_{cm}$ (tube on full length) [3.4.7]
- Member buckling strength between stitch screws $F_{ch}$ [3.4.7 for beam halves]
- Local buckling strength (web $F_{cw}$ [3.4.9] and flange $F_{cf}$ [3.4.8.1], or weighted average $F_{ca}$) [4.7.2]
- Reduced member buckling strength due to interaction between member and local buckling $F_{rc}$ [4.7.4]
### Allowable Bending Stresses for Standard Industry Profiles

<table>
<thead>
<tr>
<th>Profile</th>
<th>$S_x$</th>
<th>$F_b$</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>2X4 SMB</td>
<td>0.935</td>
<td>6.3</td>
<td>5.9</td>
</tr>
<tr>
<td>2X5 SMB</td>
<td>1.380</td>
<td>6.9</td>
<td>9.5</td>
</tr>
<tr>
<td>2X6 SMB</td>
<td>1.920</td>
<td>6.9</td>
<td>13.2</td>
</tr>
<tr>
<td>2X7 SMB</td>
<td>2.375</td>
<td>6.9</td>
<td>16.4</td>
</tr>
<tr>
<td>2X8 SMB</td>
<td>4.080</td>
<td>11.5</td>
<td>47.1</td>
</tr>
<tr>
<td>2X9 SMB</td>
<td>5.910</td>
<td>13.5</td>
<td>80.1</td>
</tr>
<tr>
<td>2X10 SMB</td>
<td>8.456</td>
<td>13.5</td>
<td>114.4</td>
</tr>
<tr>
<td>2X2 Hollow Tube</td>
<td>0.245</td>
<td>12.9</td>
<td>3.2</td>
</tr>
<tr>
<td>2X3 Hollow Tube</td>
<td>0.416</td>
<td>13.0</td>
<td>5.4</td>
</tr>
<tr>
<td>2X4 Hollow Tube</td>
<td>0.649</td>
<td>13.4</td>
<td>8.7</td>
</tr>
</tbody>
</table>
Flow Thru vs. Non-Flow Thru

HOST STRUCTURE (S.F.D.)

Flow Thru Condition

SCREEN ENCLOSURE

Flow Thru Condition

NON-Flow Thru Condition
Roof Diagonal Bracing Plan / Mansard Pool Enclosure

"Longitudinal Dimension" of Screen Enclosure

"Projection"
Typical Mansard Screen Enclosure
Simultaneous Loading Left > Right + Up

(Table 2002.4 Loading)

-3,728 lbs (uplift at corner)
2,800 lbs (tension in corner hip)

-3,728 lbs (uplift at corner)
Alternate Bracing Arrangement

-2,167 lbs

2,216 lbs

-1,972 lbs

-2,266 lbs (uplift)

• an alternative design methodology for typical aluminum patio projects of lesser complexity (not a standard)
• development beginning in 2006
• adopted into FBC 2007
• to be implemented October 2008

- developed by a statewide consensus committee of engineers, contractors and suppliers
- incorporates loads mandated by the updated Table 2002.4
- incorporates new details and advances in technology and lessons learned from failures of 2004 / 2005 storms
- more restrictive in scope (size and geometry of projects)
- for pool enclosures, upgrades eave rails, corner posts & diagonal bracing
- DRAFT COPY DOWNLOADABLE FOR FREE AT THE AAF WEBSITE (aaof.org)
Expectations

- depends upon market conditions
- new technologies: alloys, profiles
- enforcement:
  - Design (Building Department)
  - FBPE/FEMC
Resources

• AAF Website: aaof.org
• Aluminum Association: aluminum.org
  – Aluminum Design Manual
  – Screen Enclosure Design (Kissell)
  – Aluminum Structures (Kissell)

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