SUBJ: CR LAURENCE UNIVERSAL SUN SHADES

The CRL Universal Aluminum Sun Shades were evaluated in accordance with the 2006 International Building Code and the 2005 Aluminum Design Manual to determine the allowable wind and snow loads.

The sun shades will safely support the following loading:
- Distributed live load = 25 psf over projected horizontal surface
- Concentrated live load = 300#
- Wind load = 50 psf
- Snow load = 50 psf
- Snow load + Wind load = 67 psf

Loading is based on using Hilti HSL-3 concrete anchors size 8mm with 2-3/8” embedment in to concrete with a minimum strength of $f'_c = 3,000$ psi. The sunshades may be attached to structural steel using 3/8” stainless steel bolts ASTM A276-85a Condition A or stronger with the same allowable loads.

For Sunshades attached using the curtainwall brackets to aluminum framing the maximum allowable wind and snow loads are reduced to 30 psf or $S+W = 45$ psf.

For sunshades using the Zee blades wind loads are reduced by 10 psf.

For sunshades using the horizontal 1/4” flat bar blades wind and snow loads are reduced to 30 psf.

The supporting structure shall be adequate to support the reactions as shown herein.

Edward Robison, P.E.

Attachments –
Calculations: 9 pages
Shop Drawings: 2 Sheets
Calculated in accordance with SEI/ASCE 7-05 Section 6.4 SIMPLIFIED PROCEDURE.

\[ K_{zt} \] From Figure 6-4 for the site topography = 1.0.
\[ V \] = Wind speed (mph) 3 second gust
\[ p_{net30} \] = from Figure 6-3 Roof overhangs.
\[ \lambda \] = from Figure 6-3
\[ w_v = p_{net30} \times \lambda \text{ (uplift)} \]
The wind load will cause a vertical uplift force

SNOW LOADING
Calculated in accordance with SEI/ASCE 7-05 Section 7.
\[ p_t = 0.7C_eC_t p_r = 0.7 \times 1.1 \times 1.2 \times 1.0 \times p_{sf} = 0.924p_{sf} \text{ psf} \]
\[ p_s = C_s p_r = 0.58 \times p_t \text{ psf} \]
\[ p_{sf} = 5 \text{ psf for icing and rain} \]
\[ S = p_s + 5.0 = \text{ psf} \]

ICE LOADING SEI/ASCE 7-05 Section 10
1" Equivalent = 5.2 psf

SUNSCREEN LOADS:
Blades are 4’ long typical
Wind load on blades:
\[ w_v = w_h = w_{psf} \times 0.5' = 0.5w \text{ plf} \]
Snow load on blades:
\[ S = S \times 0.5' \times 0.707 = 0.354S \text{ plf} \]
Live load
\[ L = 10\text{psf} = 5\text{plf} \]
Dead load
\[ D = 1.93 \text{in}^2 \times 12''/'' \times 0.1\text{pci} = 2.32 \text{ plf} \]
Wind on Ice
\[ W_1 = w \times (6''+2\times1'')/12 = 0.667w \text{ plf} \]

Check load combinations on blades:
\[ D+L = 2.32 + 5 = 7.32 \text{ plf} \]
\[ D+0.75(L+S) = 2.32+0.75(5+0.354S) = 6.1 + 0.27S \text{ plf} \]
\[ D+S = 2.32+0.354S \text{ plf} \]
snow controls over ice
since wind is uplift only check
\[ 0.6D+W = 0.6 \times 2.32 - 0.5W \text{ plf} \]
Bending of blades:
Blade section properties based on 45° orientation:
\[ I_x = I_y = 2.487 \text{ in}^4 \]
\[ S_x = S_y = 1.150 \text{ in}^3 \]

Determine allowable stress from ADM Table 2-24
\[ F_T = 18 \text{ ksi (line 2)} \]
\[ F_C = 18 \text{ ksi (line 12)} \]
\[ R_b/t = 0.5/0.125 = 4 < 35 \]

\[ M_a = 1.15 \text{ in}^3 \times 18 \text{ ksi} = 20.3\text{k}'' = 1,725\# \]

For 4’ blades determine allowable load:
\[ U_a = 8 \times 1,725/4^2 = 862.5 \text{ plf} \]
Blade bending will not control allowable loads

Blades are attached to end bars with (4) screws

#8 countersunk screws:
\[ P_{nov} = (0.27 + 1.45t/\bar{D})Dt, F_{ty}, \text{ ADM eq 5.4.2.2-2} \]
\[ P_{nov} = (0.27 + 1.45*0.125/0.1339)*0.1339*0.125*25 \text{ ksi} = 679\# \]
\[ P_a = 679/3 = 226\# \]

\[ Z_a = 2F_{tu}D_t/n_u, \text{ ADM Eq 5.4.3-1} \]
\[ Z_a = 2*30\text{ksi}*0.1339*0.125/3 = 335\# \text{ per screw} \]

Screw shear:
\[ V_s = 0.65*33.7\text{ksi}*0.014\text{in}^2 = 307\# \]

Connection strength = 4*226# = 904# > loads

Allowable load:
\[ U_a = 904#/2' = 452\# \]
Shear connection to support outrigger bar will not control loading.

Sun shades blades are attached to 1/4” aluminum bars using the screws checked above.
Bar tapers to 8” wide at the wall bracket.
Check bar bending strength:
\[ S = 0.25**8^3/6 = 2.667 \text{ in}^3 \]
For 6061 T6 aluminum bar allowable stresses from ADM Table 2-21
\[ F_T = 28 \text{ ksi} \]
\[ F_C : (d/t)\sqrt{(L_b/d)} = (8/0.25)\sqrt{(6''/8'')} = 27.7; \]
\[ F_c = 40.5-0.927*27.7 = 14.81 \text{ ksi} \]
\[ M_a = F_bS = 14.81\text{ksi}*2.667\text{in}^3 = 39,500\text{#''} = 3,292\#' \]
Check allowable loading rate based on outrigger strength and typical 4’ sun shade width.

\[ U = \frac{(2M/L^2)}{2'} = 3,292#/L^2 \]

For standard projections of 3, 4 and 5’

- \[ U_3 = 3,292#/3^2 = 365.8 \text{ psf} \]
- \[ U_4 = 3,292#/4^2 = 205.75 \text{ psf} \]
- \[ U_5 = 3,292#/5^2 = 131.7 \text{ psf} \]

Outrigger bending strength will not control allowable loads on sun shades.
ATTACHMENT TO WALL

Ends:
Moment based on 50 psf imposed load:
\[ M = (0.6 \times 2.32 - 0.5 \times 50 \text{psf}) \times \frac{5}{2} = 329.9'\# = 3,958.8''\# \]

Bar connection to support bracket:
reaction on bolts:
about center of bracket
\[ S_{\text{bolts}} = 4 \times \sqrt{1^2 + 1.5^2} = 7.21 \text{ in} \]
\[ \phi M_n = S_{\text{bolts}} \times \phi V_{\text{NB}} \]

Bolt strength:
3/8” bolts SS:
\[ \phi V_N = 0.65 \times 54.0 \text{ksi} \times A \]
\[ \phi V_N = 0.65 \times 54.0 \text{ksi} \times 0.0775 \text{in}^2 = 2,720'\# \]

Check bearing strength on bolt holes:
allowable bearing strength from ADM Table 2-23 line 6:
\[ F_B = 21 \text{ ksi} \]
\[ B = 0.375'' \times 0.5'' \times 15 \text{ksi} = 2,813'\# \] (allowable bearing)
\[ \phi M_n = 7.21'' \times 2,720'\# = 19,614''\# \]

Determine Strength of connection to wall:
To structural steel-
Two 1/2” Bolts (ASTM A276-85a Condition B to wall
Bolt strength:
\[ \phi V_N = 0.65 \times 56.2 \text{ksi} \times A \]
\[ \phi V_N = 0.65 \times 56.2 \text{ksi} \times 0.1419 \text{in}^2 = 5,184'\# \]
\[ \phi T_N = 0.75 \times 93.7 \text{ksi} \times A \]
\[ \phi T_N = 0.75 \times 93.7 \text{ksi} \times 0.1419 \text{in}^2 = 9,972'\# \]

Moment resistance (same for downward or upward forces.)
\[ \phi M_n = \phi T_N \times (4.5'' + 1.5^2/4.5) = 5'' \times \phi T_N \]
\[ \phi M_n = 5'' \times 9,972'\# = 49,860''\# \]

Torsion load resisted by wall plate bending diagonally
between angle corner and opposite bolt:
\[ h = \sqrt{2 \times 6^2} = 8.48'' \]
3/8” thick x 8.48” high
\[ b/c = 8.48/0.375 = 22.6; \alpha_1 = 0.324, \beta_1 = 0.315 \]
\[ \tau_a = T/\alpha bc^2 \]
\[ \tau_a = 3.958.8''/[0.324 \times 8.48'' \times 0.375^3] = 10,246 \text{ psi} \]
\[ F_T = 12,500 \text{ psi} \] (ADM Table 2-23)
Angle of rotation based on plate height:
\[ \phi = TL/(\beta bc^2) \]
\[ \phi = 3.958.8'' \times 3.625''/(0.315 \times 6 \times 0.375^3 \times 3787.500) \]
\[ \phi = 0.014 \text{ rads} = 0.044'' \]
Deflection at edge of angle = 0.0046”
To Concrete:

For Hilti HSL-3 M8 anchors, \( f'_c = 3,000\text{psi} \) from ESR-1545

**Table 5 - HSL-3 Allowable Static Tension (ASD), Normal Weight Cracked Concrete (lb)**

<table>
<thead>
<tr>
<th>Nominal Anchor Diameter</th>
<th>Embedment Depth (( h_f )) (in)</th>
<th>Depth of Hilti HSL-3 (( h_h )) (in)</th>
<th>Concrete Compressive Strength (( f'_c )) (psi)</th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition A</th>
<th>Condition B</th>
</tr>
</thead>
<tbody>
<tr>
<td>M8</td>
<td>60</td>
<td>2.36</td>
<td>1,167</td>
<td>1.167</td>
<td>1,167</td>
<td>1,429</td>
<td>1,429</td>
<td>1,650</td>
<td>1,650</td>
<td>2.021</td>
<td>2.021</td>
</tr>
<tr>
<td>M10</td>
<td>70</td>
<td>2.76</td>
<td>1,867</td>
<td>1.867</td>
<td>1.867</td>
<td>2.286</td>
<td>2.286</td>
<td>2.640</td>
<td>2.640</td>
<td>3.233</td>
<td>3.233</td>
</tr>
<tr>
<td>M12</td>
<td>80</td>
<td>3.15</td>
<td>3,147</td>
<td>3,147</td>
<td>3,147</td>
<td>3,506</td>
<td>3,506</td>
<td>3,998</td>
<td>3,998</td>
<td>5,567</td>
<td>5,567</td>
</tr>
<tr>
<td>M16</td>
<td>100</td>
<td>3.94</td>
<td>4,292</td>
<td>4,292</td>
<td>4,292</td>
<td>5,501</td>
<td>5,501</td>
<td>6,352</td>
<td>6,352</td>
<td>7,759</td>
<td>7,759</td>
</tr>
<tr>
<td>M20</td>
<td>125</td>
<td>4.92</td>
<td>6,277</td>
<td>6,277</td>
<td>6,277</td>
<td>7,658</td>
<td>7,658</td>
<td>8,717</td>
<td>8,717</td>
<td>10,873</td>
<td>10,873</td>
</tr>
<tr>
<td>M24</td>
<td>150</td>
<td>5.91</td>
<td>8,252</td>
<td>8,252</td>
<td>8,252</td>
<td>10,106</td>
<td>10,106</td>
<td>11,670</td>
<td>11,670</td>
<td>14,292</td>
<td>14,292</td>
</tr>
</tbody>
</table>

1. Values are for single anchors with no edge distance or spacing reduction. For other cases, see ESR-1545 Section 4.2 Eq. 5.
2. Values are for normal weight concrete. For sand lightweight concrete, multiply values by 0.85. For all-lightweight concrete, multiply values by 0.75. See ACI 318-05 Section D 3.4.
3. Condition A applies where the potential concrete failure surfaces are crossed by supplementary reinforcement proportioned to that the potential concrete failure plane into the structural member. Condition B applies where such supplementary reinforcement is not provided, or where pullout or pryout strength governs.
4. Allowable static load cases for 2,500 psi are calculated by multiplying the pullout strength \( N_{pl} \), the strength reduction factor of 0.65 and dividing by an \( n \) of 1.4 according to ICC ESR-1545 Section 4.2. See Table 2 for \( N_{pl} \). This load may be adjusted for other concrete strengths according to ICC ESR-1545 Section 4.1.3 by using the following equation.

\[
N_{pl,\text{red}} = N_{pl} \cdot \frac{f'_c}{2500}
\]

\[
T_c = 1,429\#
\]

Allowable moment on bracket:

\[
M_a = 1,429\# \cdot \{4.5" \cdot 0.5 \times [1,429\#/\{6" \cdot 2 \cdot 3,000\psi\}]\} = 6,402"\#
\]

Anchorage to concrete is adequate for 50psf imposed loading.

**BRACKET MUST HAVE SOLID BACKING TO PREVENT TORSION FAILURE.**

**FOR END BRACKET STRENGTH THE MAXIMUM ALLOWABLE IMPOSED LOADS ARE 50 PSF (WIND OR SNOW)**
CENTER TEE BRACKET
Load at center bars is double because bracket is loaded from two bars.
For center bars bolts will be in double shear so bolt strength is adequate.
\[ M = 2 \times 3,958.8" \# = 7,917.6" \# \]

Check bearing on bracket:
\[ B = 3/8" \times 0.5" \times 15 \text{ksi} = 2,812.5" \#
\]
total allowable moment on the bracket based on bolt bearing:
\[ S_{\text{bolts}} = 4 \times \sqrt{(1^2 + 1.5^2)} = 7.21 \text{ in} \]
\[ \phi M_n = S_{\text{bolts}} \phi V_{\text{NB}} \]
\[ \phi M_n = 7.21" \times 2,812.5" = 20,278" \#
\]
Blade to bracket connection will not control.

Check torsion strength of tee:
Torsion load resisted by wall plate bending diagonally between angle corner and opposite bolt:
\[ \text{torsion in flange} = 3,958.5" \# \text{ each} \]
\[ h = \sqrt{2 \times 6^2} = 8.48" \]
3/8" thick x 8.48" high
\[ b/c = 8.48/0.375 = 22.6; \alpha_1 = 0.324, \beta_1 = 0.315 \]
\[ \tau_a = T/\alpha bc^2 \]
\[ \tau_a = 3,958.8" \#/[0.324 \times 8.48" \times 0.375^2] = 10,246 \text{ psi} \]
\[ F_c = 12,500 \text{ psi (ADM Table 2-23)} \]
Angle of twist will be 1/2 that of for the end bracket which is very small.

Anchorage strength to wall is 2 times the anchorage for the end bracket therefore is adequate for the 50 psf imposed load case.
CURTAINWALL CONNECTION BRACKET:

Connection to outrigger is the same as previously checked therefore okay.

Check connection to supporting structure.

#10 self drilling screws into 0.125” aluminum.

Screw pullout:
\[ P_{not} = K_s D t F_{ty2} \]
\[ K_s = 1.20 \]
\[ D = 0.19 \text{ in} \]
\[ t_c = 0.125” \]
\[ F_{ty2} = 16 \text{ ksi} (6063-T5) \]
\[ P_{not} = 1.2 \times 0.19 \times 0.125 \times 16 \text{ksi} = 456\# \]
\[ P_a = 456\# / 3 = 152\# \]

For 5 screws top and bottom, reaction point will be approximated by edge of connection blade:
\[ \sum P_a z = 5 \times 152\# \times (9”) = 6,840\#” \]

Check allowable load sunshade when installed with curtain wall bracket:

For center section, 5’ projection and supports at 4’ on center:
\[ w = 2 \times (6,840/12) / 5^2 = 45.6 \text{ plf} \]

For 4” members:
\[ w = 45.6 \text{plf} / (0.33 \times 4’) = 34.2 \text{ psf} \]
for S or W = 30 psf.

for Zee blade: 6” horizontal projection
\[ w = 45.6 \text{plf} / (0.5 \times 4’) = 22.8 \text{ psf} \]
for S or W = 20 psf.
Check Alternative Blades:

Z blade check bending strength of blade:
Properties for loading perpendicular to blade web (wind only)
\[ b = 7.124'' \]
\[ I_{xx} = 0.0774 \text{ in}^4 \]
\[ S_{xx} = 0.0968 \text{ in}^3 \]
For in plane bending
\[ F_b = 12.5 \text{ ksi} \]
\[ M_a = 0.0968 \text{ in}^3 \times 12,500 \text{ psi} = 1,210'' \#

For 4’ blade length:
Allowable load on blade-
\[ w = \frac{4 \times 1,210'' \#}{12 \times 4^2} = 25.2 \text{ plf} \]
\[ W = 25.2 / 0.594 = 42.4 \text{ psf} \]

Connection strength to support outrigger is 3/4 of previously checked (page 3) and will not control loading.

ALLOWABLE WIND LOAD FOR Z BLADE IS 42.4 psf.

4” Round
\[ I = 1.21 \text{ in}^4 \]
\[ S = 0.605 \text{ in}^3 \]
Connection to support outrigger uses 4 screws - okay

4” Round blade strength and connections will not control allowable loads.

4” Square
\[ I = 2.055 \text{ in}^4 \]
\[ S = 1.027 \text{ in}^3 \]
Connection to support outrigger uses 4 screws - okay

4” Square blade strength and connections will not control allowable loads.
4” x 1” Rectangular blade:

\[ I = 0.0964 \text{ in}^4 \]
\[ S = 0.1928 \text{ in}^3 \]
\[ F_{b} = 9.5 \text{ ksi ADM Table 2-23 line 14} \]
\[ M_a = 0.1928 \text{ in}^3 * 9,500 \text{ psi} = 1.832''# \]

\[ w = \frac{4 \times 1.832''#}{(12 \times 4^2)} = 38.17 \text{ plf} \]
\[ W = \frac{38.17}{0.333} = 114.6 \text{ psf} \]

Connection to support outrigger uses 2 screws
\[ V_a = 226''# \times 2 \text{ screws} = 452''# \text{ (see page 3)} \]
\[ W = \frac{452''#}{(0.333'' \times 4'/2)} = 678 \text{ psf} \]
Connection strength doesn’t control.

4” Airfoil blade
Check based on weak axis bending (wind load)
\[ I = 0.0954 \text{ in}^4 \]
\[ S = 0.1513 \text{ in}^3 \]
\[ F_{b} = 11.5 \text{ ksi ADM Table 2-23 line 12} \]
\[ M_a = 0.1513 \text{ in}^3 * 11,500 \text{ psi} = 1.740''# \]

\[ w = \frac{4 \times 1.740''#}{(12 \times 4^2)} = 36.25 \text{ plf} \]
\[ W = \frac{36.25}{0.333} = 108.9 \text{ psf} \]

Connection to support outrigger uses 3 screws
\[ V_a = 226''# \times 3 \text{ screws} = 678''# \text{ (see page 3)} \]
\[ W = \frac{678''#}{(0.333'' \times 4'/2)} = 1,017 \text{ psf} \]
Connection strength doesn’t control.

1/4”x 4” Flat Bar blade
\[ I = 4'' \times 0.25'^3/12 = 0.00521 \text{ in}^4 \]
\[ S = 4'' \times 0.25'^3/12 = 0.02083 \text{ in}^3 \]
\[ F_{b} = 12.5 \text{ ksi ADM Table 2-23 line 13} \]
\[ M_a = 0.02083 \text{ in}^3 * 12,500 \text{ psi} = 260.4''# \]

\[ w = \frac{8 \times 260.4''#}{(12 \times 4^2)} = 10.85 \text{ plf} \]
\[ W = \frac{10.85}{0.333} = 32.6 \text{ psf} \]

Connection to support outrigger:
1/8” fillet weld along one face of bar:
\[ V_w = 0.125'' \times (4 - 2 \times 0.75'') \times 2.8 \text{ ksi} = 875''# \]
Connection strength will not control allowable load on flat bar blade.