Structural Calculations for
Residential/Commercial
Aluminum Cable Guardrail System

Prepared for
Stainless Cable Solutions
15806 SE 114th Ave
Clackamas, OR. 97015

April 27, 2018
17067.00
Scope of Work
Development and design for an aluminum cable railing system including:
Termination post, intermediate post, top rail, rail connecting blocks, cables, end cap, flat infill, base plate,
stair facia, stair intermediate cap, and attachments.

General
The enclosed calculations were intended to be designed and submitted in conformance with the following:
Professional Engineer Seals
State of Oregon

Building Codes (Meets or Exceeds Requirements)
2014 Oregon Structural Specialty Code and Oregon Residential Specialty Codes

Additional Design References
2010 Aluminum Design Manual
2011 Building Code Requirements for Structural Concrete (ACI318-11)
AISC Steel Construction Manual, 14th Edition
2012 National Design Specification for Wood Construction
ICC Report AC273: Acceptance Criteria for Handrails and Guards

Materials
<table>
<thead>
<tr>
<th>Material Description</th>
<th>Tensile Ultimate Strength, $F_u$</th>
<th>38 ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>6061-T6, T6510, T6511 Extrusions</td>
<td>Tensile Yield Strength, $F_y$</td>
<td>35 ksi</td>
</tr>
<tr>
<td></td>
<td>Compressive Yield Strength, $F_{cy}$</td>
<td>35 ksi</td>
</tr>
<tr>
<td></td>
<td>Shear Ultimate Strength, $F_u$</td>
<td>24 ksi</td>
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<tr>
<td>A554 Stainless Steel Grade 304/304L</td>
<td>Yield Stress, $F_y$</td>
<td>30 ksi</td>
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<tr>
<td></td>
<td>Tensile Stress, $F_u$</td>
<td>90 ksi</td>
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<tr>
<td>Type 316 Stainless Steel Wire Rope</td>
<td>1x19 Strand Core</td>
<td>1/8&quot; dia. with breaking strength = 1,869-lbs</td>
</tr>
<tr>
<td></td>
<td>7x7 Strand Core</td>
<td>1/8&quot; dia. with breaking strength = 1,566-lbs</td>
</tr>
</tbody>
</table>
Guardrail Loading Conditions

**Uniform Load**
- Per 2012 IBC §1607.8.1, the uniform load shall be applied to the handrail in any direction. The railing system covered in this package covers all commercial and residential properties.

\[ p = 50 \text{ plf} \]

**Concentrated Load**
- Per IBC §1607.8.1.1, the concentrated load shall be applied to the handrail in any direction
- Per IBC §1607.8.1.2, components including intermediate rails, balusters, and cables shall be designed for a concentrated load applied normal and horizontally over an area of 1ft².

\[ P = 200 \text{ lbs} \]

\[ P = 50 \text{ lbs} \]

Per IBC §1013.2 and IRC §312.3 opening limitations shall not allow the passage of a sphere 4" in diameter through.

### Part Numbers and Descriptions

- **IP100** - SCRS Extruded Aluminum Intermediate Posts
- **TR100** - SCRS Extruded Aluminum Top Rail
- **FI200** - SCRS Extruded Aluminum Flat Infill
- **EC100** - SCRS Top Rail End Cap
- **BP100** - SCRS Base Plate
- **SR200** - SCRS Extruded Aluminum Stair Rail
- **RCB100** - SCRS Stair Grab Rail Connecting Block
- Stainless Steel Wire Rope
- **TP100** - SCRS Extruded Aluminum Termination Posts
- **ISPA200** - SCRS Stair Post Cap Assembly
- SCRS Extruded Aluminum Facia Mount Posts

### Aluminum Cable Guardrail System Summary

- Total Post/Handrail Height Including Base Plate: 42 in
- Maximum Termination Post Spacing: 5 ft
- Maximum Stair Rail Post Spacing: 5 ft
- Cable Prestressing: 255 lbs
- Cable Spacing (On-Center): 3.125 in
Extruded Aluminum Post Input

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Post Spacing, s =</td>
<td>5 ft</td>
</tr>
<tr>
<td>Applied Load At Top, P =</td>
<td>250 lbs</td>
</tr>
<tr>
<td>Unbraced Length, Lb =</td>
<td>45.500 in</td>
</tr>
<tr>
<td>Post Area, Ap =</td>
<td>1.146 in²</td>
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<tr>
<td>Compressive Modulus of Elasticity, E =</td>
<td>10100 ksi</td>
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<tr>
<td>Section Modulus, S =</td>
<td>0.744 in²</td>
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<tr>
<td>Moment of Inertia, Ix &gt; Iy =</td>
<td>0.837 in⁴</td>
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<tr>
<td>Torsion Constant, J =</td>
<td>0.073 in</td>
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<tr>
<td>Clear Height of Shear Area, h =</td>
<td>2.250 in</td>
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<tr>
<td>Thickness of Shear Area, t =</td>
<td>0.125 in</td>
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<tr>
<td>Slenderness, S =</td>
<td>16.0</td>
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<tr>
<td>Allowable Stress, S1 =</td>
<td>21.2 ksi</td>
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<tr>
<td>Slenderness Limit, S1 =</td>
<td>21</td>
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<tr>
<td>Allowable Stress, S2 &lt; S1 =</td>
<td>22.6 ksi</td>
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<td>Slenderness Limit, S2 =</td>
<td>33</td>
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<td>Allowable Stress, S2 ≤ S2 =</td>
<td>36.3 ksi</td>
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<td>Allowable Bending Stress, Fb =</td>
<td>21.2 ksi</td>
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<tr>
<td>Allowable Moment, S*Fc =</td>
<td>15.779 kip-in</td>
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<tr>
<td>Applied Moment, Pls =</td>
<td>11.38 kip-in</td>
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Flat Elements Supported on Both Ends in Uniform Compression, 6061-T6 (ADM 2010 Section B5.4.2, Table 2-19 Part VI)

<table>
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<td>Slenderness, S =</td>
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<td>Allowable Stress, S1 =</td>
<td>-5.42 ksi</td>
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<td>Slenderness Limit, S1 =</td>
<td>55</td>
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<td>Allowable Stress, S2 ≤ S1 =</td>
<td>19.961 ksi</td>
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<td>Slenderness Limit, S2 =</td>
<td>1.685</td>
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<tr>
<td>Allowable Stress, S2 ≤ S2 =</td>
<td>1.159 ksi</td>
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<td>Allowable Bending Stress, Fb =</td>
<td>20.0 ksi</td>
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<td>Allowable Moment, S*Fc =</td>
<td>15.283 ksi</td>
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<tr>
<td>Applied Bending Stress, Fb =</td>
<td>11.38 kip-in</td>
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Deflection Check, Δmax = Lb/12 (ICC Report AC273)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Allowable Deflection, Δallow =</td>
<td>3.792 in</td>
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<tr>
<td>Applied Deflection, PLb²/3EI = Δapplied =</td>
<td>0.928 in</td>
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Shear in Elements, Gross Section 6061-T6 (ADM 2010 Table Section G.2, Table 2-19 Part VI)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Allowable Stress, SSS1 =</td>
<td>12.7 ksi</td>
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<tr>
<td>Slenderness Limit, S1 =</td>
<td>35.3</td>
</tr>
<tr>
<td>Allowable Stress, S1 ≤ S2 =</td>
<td>14.8 ksi</td>
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<tr>
<td>Slenderness Limit, S2 =</td>
<td>63.0</td>
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<tr>
<td>Allowable Stress, S2 ≤ S2 =</td>
<td>151.0 ksi</td>
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<tr>
<td>Allowable Shear Stress, Fs =</td>
<td>13 ksi</td>
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<tr>
<td>Allowable Shear, Ap*Fs = Vallow =</td>
<td>14.557 kips</td>
</tr>
<tr>
<td>Applied Shear, P = Vapplied =</td>
<td>0.250 kips</td>
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Core Mounted Posts Bearing Check

- Existing Concrete Strength, \( f'c \) = 2500 psi
- \( V_{\text{applied}} \) = 0.250 kips (See Page 4)
- \( M_{\text{applied from post}} \) = 11.375 kip-in (See Page 4)
- \( M_{\text{applied from shear}} \) = 0.750 kip-in
- \( M_{\text{total}} \) = 12.125 kip-in
- Depth of Concrete Blockout, \( d_{\text{blockout}} \) = 3.000 in
- Distance Bottom of Blockout to Applied Pu, \( d_{\text{compb}} \) = 2.000 in
- Width of Post, \( d_{\text{term}} \) = 2.250 in
- Loaded Area, \( A_1 \) = 2.250 in²
- Area of the Lower Base of Largest Fulcrum, \( A_2 \) = 6.500 in²
- Compression Load at Blockout, Pu = 6.063 kips
- Strength Reduction Factor, \( \Phi \) = 0.65 (Per ACI 318-11 §9.3.2.4)
- Concrete Bearing Strength, \( f_{\text{b}} \) = 5282 psi (Per ACI 318-11 §10.14.1)
- Maximum Applied Compression Load, \( f_{\text{bmax}} \) = 2694 psi OK < 5282 psi

Core Mounted Posts Edge Distance Check

- Distance from Center of Post to Edge of Concrete, \( c_{a1} \) = 6.750 in
- Distance from Post Face to Edge of Concrete, \( c_{\text{post}} \) = 4.500 in
- Thickness of Concrete, \( h_{a1} \) = 4.000 in
- Projected Concrete Failure Area, \( A_{Vco} \) = 205.031 in² (Per ACI 318-11 §D.6.2.1 D-32)
- Projected Concrete Failure Area, \( A_{Vc} \) = 90,000 in² (Per ACI 318-11 §D.6.2.1 D-32)
- Shear Strength Modification Factor, \( \psi_{ed,V} \) = 1.00 (Per ACI 318-11 §D.6.2.6)
- Cracked Concrete Modification Factor, \( \psi_{c,V} \) = 1.00 (Per ACI 318-11 §D.6.2.7)
- Cracked Concrete Modification Factor, \( \psi_{h,V} \) = 1.59 (Per ACI 318-11 §D.6.2.8)
- Lightweight Concrete Factor, \( \lambda \) = 1.00 (Per ACI 318-11 §8.6.1)
- Basic Concrete Breakout Strength, \( V_b \) = 9,752 kips (Per ACI 318-11 §D.6.2.1 D-31)
- Nominal Concrete Breakout Strength, \( V_{cb} \) = 6,811 kips (Per ACI 318-11 §D.6.2.1 D-31)
- Max Nominal Concrete Breakout Strength, \( V_{\text{max}} \) = 6,811 kips OK < 6,0625 kips

Check Top Connection

- Use 4,000 psi Non-Shrink Grout in Min 3"x4 Deep Blockout or 3" Dia x 4" Deep Hole with 4 ½” Min Edge Distance (No Rebar) or 1 ½” Min Edge Distance when #3 or Larger Slab Edge Rebar Present

Note: Lateral loads on top rail bears directly on post side. Only uplift loads affecting attachment are considered.

- Diameter of Screw, \( d_{\text{screw}} \) = 0.194 in
- Thickness of Post, \( t_{\text{post}} \) = 0.125 in
- Area of Engaged Post in Shear, \( A_{Vpost} \) = 0.024 in²
- Number of Screws in Shear = 2
- Tensile Ultimate Strength of Member Not in Contact with Screw Head, \( F_{tu2} \) = 38 ksi
- Shear Strength of Screw, \( V_{\text{screw}} \) = 0.614 kips OK > 0.250 kips
Extruded Aluminum Rail Input

Post Spacing, \( s = 5 \text{ ft} \)

(See Page 3) Applied Load At Top, \( P = 250 \text{ lbs} \)

Unbraced Length, \( L_a = 5'-0" \times 12" - 2.25" = 57.750 \text{ in} \)

Compressive Modulus of Elasticity, \( E = 10100 \text{ksi} \)

Rail Area, \( A_r = 0.928 \text{ in}^2 \)

Torsion Constant, \( J = 0.005 \text{ in} \)

Moment of Inertia \( x \), \( I_{xx} = 0.212 \text{ in}^4 \)

Clear Height of Shear Area, \( h = 1.643 \text{ in} \)

Thickness of Shear Area, \( t = 0.090 \text{ in} \)

Flexural Compression Closed Shapes Lateral Torsional Buckling

6061-T6 (ADM 2010 Section F3.1, Table 2-19 Part VI)

Slenderness, \( S = 469.7 \)

Allowable Stress, \( S_{S1} = -19.26 \text{ ksi} \) ▲ Controls

Stiffness Limit, \( S_1 = 55 \)

Allowable Stress, \( S_1 < S_2 = 18.742 \text{ ksi} \)

Stiffness Limit, \( S_2 = 1685 \)

Allowable Stress, \( S_{S2} = 0.394 \text{ ksi} \)

Applied Moment, \( P*L_B/4 = 3.609 \text{ kip-in} \)

Allowable Bending Stress, \( F_b = 18.7 \text{ ksi} \)

Vertical Compressive Stress Applied, \( C_{\text{Vert}} = 9.672 \text{ ksi} \) OK

Horizontal Compressive Stress Applied, \( C_{\text{Horiz}} = 4.109 \text{ ksi} \) OK

Flat Elements Supported on Both Ends in Uniform Tension

6061-T6 (ADM 2010 Section F8.1, Table 2-19 Part VI)

Tensile Yield Strength, \( F_{ty} = 35 \text{ ksi} \)

Factor of Safety on Yield Strength, \( n_y = 1.65 \)

Allowable Tensile Stress, \( F = 21 \text{ ksi} \)

Tensile Ultimate Strength, \( F_{tu} = 38 \text{ ksi} \)

Factor of Safety on Ultimate Strength, \( n_u = 1.95 \)

Coefficient for Tension Members, \( k_s = 1.00 \)

Allowable Tensile Stress, \( F = 19.5 \text{ ksi} \) ▲ Controls

Vertical Tensile Stress Applied, \( T_{\text{Vert}} = 18.999 \text{ ksi} \) OK

Horizontal Tensile Stress Applied, \( T_{\text{Horiz}} = 4.109 \text{ ksi} \) OK

Deflection Check, \( \Delta_{\text{MAX}} = L_a/12 \) (ICC Report AC273)

Allowable Deflection, \( \Delta_{\text{ALLOW}} = 4.813 \text{ in} \)

Applied Deflection, \( PL_E^3/4BEI = 0.468 \text{ in} \) OK

Shear in Elements, Gross Section 6061-T6 (ADM 2010 Table Section G.2, Table 2-19 Part VI)

Slenderness, \( S = 14.3 \)

Allowable Stress, \( S_{S1} = 12.7 \text{ ksi} \) ▲ Controls

Stiffness Limit, \( S_1 = 35.3 \text{ in}^3 \)

Allowable Stress, \( S_1 < S_2 = 14.970 \text{ ksi} \)

Stiffness Limit, \( S_2 = 63 \text{ in}^3 \)

Allowable Stress, \( S_{S2} = 189.080 \text{ ksi} \)

Allowable Shear Stress, \( F_s = 189.1 \text{ ksi} \)

Allowable Shear, \( A_p*F_s = 11.780 \text{ kips} \)

Applied Shear, \( P = 0.250 \text{ kips} \) OK
**Tension Capacity of Screw (ADM 2010 Section J5.5)**

Screw Properties: 5/16"-18 x 2" 6-Lobe Flat Head Floorboard Thread Cutting Screw, Type F, Black Phosphate and Oil

\[ \text{Fu} = 120 \text{ ksi, Fy} = 48 \text{ ksi, Ft} = 90 \text{ ksi, Min Dia} = 0.3026 \text{ in, Area} = 0.0702 \text{ in}^2 \]

\[ M_{\text{APPLIED}} = \text{Load x Length} = 10,500 \text{ kip-in} \]

Number of Screws in Tension = 2

Resisting Moment Arm, Center of Screw to Compression Face, \( l_{\text{arm}} = 2.00 \text{ in} \)

Tension Applied, \( P_{\text{APPLIED}} = 2.625 \text{ kips} \)

Thread Stripping Area of Internal Thread Per Inch, \( A_{\text{sn}} = 0.663 \text{ in}^2 \)

Depth of Full Thread Engagement into \( t_1, t_{\text{cmin}} = 1.00 \text{ in} \)

Tensile Ultimate Strength of Member Not in Contact with Screw Head, \( F_{\text{tu}} = 38 \text{ ksi} \)

Nominal Pull-Out Strength, \( P_{\text{not}} = 14.613 \text{ kips} \) (Eq. J5.3)

Thickness of Member in Contact with Screw Head, \( t_1 = 0.375 \text{ in} \)

Tensile Yield Strength of Member in Contact with Screw Head, \( F_{\text{ty}} = 35 \text{ ksi} \)

Nominal Screw Head Diameter Abs Min, \( D = 0.568 \text{ in} \)

\( t_1/D = 0.66 < 1.1 \)

Nominal Pull-Over Strength, \( P_{\text{nov}} = 9.150 \text{ kips} \) (Eq. J5.10)

Tensile Strength of Screw, \( F_{\text{t}} = 90 \text{ ksi} \)

Tensile Stress Area of Screw, \( A_{\text{t}} = 0.072 \text{ in}^2 \)

Nominal Tensile Strength of a Screw, \( P_{\text{nt}} = 6.480 \text{ kips} \)

Factor of Safety on Screw Connections, \( n_s = 3.00 \)

\( \Omega = 2.00 \)

Pull-Out Strength, \( P_{\text{not}}/n_s = 4.871 \text{ kips} \) OK > 2.625 kips

Pull-Over Strength, \( P_{\text{nov}}/n_s = 3.050 \text{ kips} \) OK > 2.625 kips

Tensile Strength, \( P_{\text{nt}}/\Omega = 3.240 \text{ kips} \) OK > 2.625 kips

**Shear Capacity of Screw (ADM 2010 J5.6)**

\[ V_{\text{APPLIED}} = 1.658 \text{ kips} \] (TP-1)

Number of Screws in Shear = 4

Shear Applied, \( V_{\text{APPLIED}} = 0.414 \text{ kips Per Screw} \)

Tensile Ultimate Strength of Member in Contact with Screw Head, \( F_{\text{tu}} = 38 \text{ ksi} \)

Factor of Safety on Ultimate Strength, \( n_u = 1.95 \)

Check 1) Screw Shear and Bearing Strength, \( P_v = 6.099 \text{ kips} \) (Eq. J5.12)

Thickness of Member Not in Contact with Screw Head, \( t_2 = 1.000 \text{ in} \)

Check 2) Screw Shear and Bearing Strength, \( P_v = 11.069 \text{ kips} \) (Eq. J5.12)

Check 3) Screw Shear and Bearing Strength, \( P_v = N/A \) (Eq. J5.13)

Nominal Shear Strength of a Screw, \( P_{\text{ss}} = 5.522 \text{ kips} \)

Check 4) Screw Shear and Bearing Strength, \( P_v = 1.473 \text{ kips} \) (Eq. J5.14)

Minimum Screw Shear and Bearing Strength, \( P_{v\text{min}} = 1.473 \text{ kips} \) OK > 0.414 kips
**Base Plate Anchorage (Lag Screws) Per 2012 National Design Specification for Wood Construction**

- **Applied Moment** at TP100, \( M_{applied} = 11.375 \text{ kip-in} \) (Page 4)
- **Edge of Baseplate to Centerline of Tension Anchorage**, \( l_{anc} = 4.360 \text{ in} \)
- **Number of Screws in Tension** = 2
- **Applied Tension at Anchor Bolt/Screw**, \( V_{applied} = 1.304 \text{ kips} \) (Page 4)
- **Number of Screws in Shear** = 4
- **Shear Applied**, \( V_{applied} = 0.250 \text{ kips} \)
- **Lag Screw Reference Withdrawal Design Value** (G=0.46, D=3/8"), \( W = 269 \text{ lbs} \) (Per Table 11.2A)
- **Penetration Depth**, \( d = 4.500 \text{ in} \)
- **Allowable Lag Screw Tension**, \( T_{allowable} = 1.937 \text{ kips} \)
- **Allowable Lag Screw Shear**, \( V_{allowable} = 0.170 \text{ kips} \)

Use (4) ⅜" Dia SS304 Lag Screws with 6" Min Penetration into Min (1) 6x6 or (2) 3x6 Hem-Fir #2 (1.5" Min Edge Distance)

**Base Plate Anchorage (Thru-Bolts) Per 2012 National Design Specification for Wood Construction**

- **Bolt diameter** = 0.375 in
- **Diameter of washer** = 2.500 in
- **Area of Bearing under washer** = 4.758 in²
- **Washer bearing, \( F_{penn} \)** = 521 psi (Per Table 4A)
- **Allowable Thru-Bolt Tension**, \( T_{allowable} = 2.209 \text{ kips} \)
- **Allowable Thru-Bolt Shear**, \( V_{allowable} = 0.170 \text{ kips} \)

Use (4) ⅜" Dia SS304 Thru-Bolts with Min 2" Dia Heavy Washer into Min (1) 6x or (2) 3x Hem-Fir #2
Extruded Aluminum Rail Input

- Post Spacing, s = 5 ft
- Left/Right to Centroid, c_{center} = 0.877 in
- Applied Load At Top, P = 250 lbs
- Section Modulus Top, S_{xx} = 0.414 in³
- Unbraced Length, L_{B} = 57.750 in
- Section Modulus Bottom, S_{xx} = 0.296 in³
- Compressive Modulus of Elasticity, E = 10100 ksi
- Section Modulus, S_{yy} = 0.350 in³
- Rail Area, A_r = 0.761 in²
- Torsion Constant, J = 0.005 in
- Moment of Inertia x, I_{xx} = 0.467 in⁴
- Clear Height of Shear Area, h = 2.660 in
- Thickness of Shear Area, t = 0.090 in
- Top of Member to Centroid, c_{top} = 1.128 in
- Bottom of Member to Centroid, c_{bott} = 1.577 in

Flexural Compression Closed Shapes Lateral Torsional Buckling
6061-T6 (ADM 2010 Section F3.1, Table 2-19 Part VI)

- Slenderness, S = 1238.1
- Allowable Stress, S_S1 = -55.78 ksi
- Slenderness Limit, S_1 = 55
- Allowable Stress, S_1 < S_2 = 15.525 ksi
- Slenderness Limit, S_2 = 1685
- Allowable Stress, S_2 > S_1 = 0.057 ksi
- Applied Moment, P*L_{B}/4 = 3.609 kip-in
- Allowable Bending Stress, F_b = 15.5 ksi
- Vertical Compressive Stress Applied, C_{Vert} = 8.719 ksi
- Horizontal Compressive Stress Applied, C_{Horiz} = 10.321 ksi

Flat Elements Supported on Both Ends in Uniform Tension
6061-T6 (ADM 2010 Section F8.1, Table 2-19 Part VI)

- Tensile Yield Strength, F_{py} = 35 ksi
- Factor of Safety on Yield Strength, n_{y} = 1.65
- Allowable Tensile Stress, F = 21 ksi
- Tensile Ultimate Strength, F_{u} = 38 ksi
- Factor of Safety on Ultimate Strength, n_{u} = 1.95
- Coefficient for Tension Members, k_{t} = 1.00
- Allowable Tensile Stress, F = 19 ksi
- Vertical Tensile Stress Applied, V_{vert} = 12.188 ksi
- Horizontal Tensile Stress Applied, V_{horiz} = 10.321 ksi

Deflection Check, \Delta_{MAX} = L_{B}/12 (ICC Report AC273)

- Allowable Deflection, \Delta_{ALLOW} = 4.813 in
- Applied Deflection, \Delta_{APPLIED} = 0.213 in

Shear in Elements, Gross Section 6061-T6 (ADM 2010 Table Section G.2, Table 2-19 Part VI)

- Slenderness, S = 25.6
- Allowable Stress, S_S1 = 12.7 ksi
- Slenderness Limit, S_1 = 35.3 in³
- Allowable Stress, S_1 < S_2 = 13.761 ksi
- Slenderness Limit, S_2 = 63 in³
- Allowable Stress, S_2 > S_1 = 58.998 ksi
- Allowable Shear Stress, F_s = 12.7 ksi
- Applied Shear, P = 0.250 kips
Check Fascia Mount

Note: Uses [2] #10-12x1 1/2" Phillips Pan Head Sheet Metal Screws - Type A, 18-8 Stainless Steel

- Diameter of Screw, $d_{screw} = 0.189$ in
- Thickness of Post, $t_{post} = 0.125$ in
- Area of Engaged Post in Shear, $A_{Vpost} = 0.024$ in$^2$
- Number of Screws in Shear = 2
- Factor of Safety on Screw Connections, $n_s = 3.00$

Tensile Ultimate Strength of Member Not in Contact with Screw Head, $F_{tu2} = 38$ ksi

Shear Strength of Screw, $V_{screw} = 0.599$ kips OK > 0.250 kips

Note: Uses [2] #10-16x3/4" Phillips Pan Head Self Drilling Screw Zinc #3 Point

- Diameter of Screw, $d_{screw} = 0.194$ in
- Thickness of Post, $t_{post} = 0.125$ in
- Area of Engaged Post in Shear, $A_{Vpost} = 0.024$ in$^2$
- Number of Screws in Shear = 2
- Factor of Safety on Screw Connections, $n_s = 3.00$

Tensile Ultimate Strength of Member Not in Contact with Screw Head, $F_{tu2} = 38$ ksi

Shear Strength of Screw, $V_{screw} = 0.614$ kips OK > 0.250 kips

Check Stair Rail Adapter

Note: Uses [2] #10-16x3/4" Phillips Pan Head Self Drilling Screw Zinc #3 Point See Check Above

- Applied Shear, $V_{base} = V_{conn} = V_{applied} = 1.658$ kips
- Distance from Center of Bolt to Face of Base, $l_{arm} = 0.655$ in
- Applied Moment, $M_{applied} = 1.085$ kip-in
- Distance from Edge of Base to Center of Screw, $l_{base} = 1.450$ in
- Applied Tension, $T_{applied} = 0.749$ kips

- Diameter of Screw, $d_{screw} = 0.194$ in
- Thickness of Post, $t_{post} = 0.125$ in
- Area of Engaged Post in Shear, $A_{Vpost} = 0.024$ in$^2$
- Number of Screws in Shear = 2
- Factor of Safety on Screw Connections, $n_s = 3.00$

Tensile Ultimate Strength of Member Not in Contact with Screw Head, $F_{tu2} = 38$ ksi

Shear Strength of Screw, $V_{screw} = 0.614$ kips OK > 0.250 kips
Check Cable Deflection

Note: A min load of 50psf shall be applied to a 4" sphere. Spacing and deflection of the cables shall not allow the sphere to pass through.

- Diameter of Cable, D = 0.125 in
- Intermediate Post Spacing, L = 5 ft
- Prestress Force, Fps = 255 lbs
- Sphere Diameter, Db = 4.000 in
- Initial Cable Spacing, So = 3.125 in
- Termination Post Spacing, Lt = 30 ft
- Load Applied to Sphere, wsphere = 50.0 psf
- Projected Area of Sphere, Asphere = 12.566 in²
- Impact Factor, i = 2.00
- Force Applied to Sphere, Fxsphere = 8.727 lbs
- Spread at Pass-Thru = Db+Dcable, Smax = 4.125 in
- Final Cable Spacing, Sfinal = Seq = 4.124 in
- Deflection at Pass-Thru = (Smax-So)/2. Δmax = 0.500 in
- Deflection, Δ = Δeq = 0.500 in
- Applied Angle = asin((So+2Δ)/(Db+D)). θ = 88.7°
- Force Applied to Cable, T = F = 198.171 lbs
- Maximum Cable Deflection = (Db+Dc-So)/2. Constant
- Modulus of Elasticity, E = 29000 ksi
- Moment of Inertia, I = 0.00001198 in⁴
- Cross Sectional Area, A = 0.012 in²
- Extensible, Flexible Cable, Pef = 0.274 lbs
- Flexural Bending, Pfb = 0.039 lbs
- Prestressing, Pps = 8.492 lbs
- Force in Cable Resisting Sphere, Fxcable = P = 8.804 lbs
- 1/8" Diameter 1x19 Strand Core Breaking Strength = 1869 lbs
- 1/8" Diameter 7x7 Strand Core Breaking Strength = 1566 lbs

\[ P_{ef} = \frac{4AE\Delta}{L} \times \frac{\sqrt{4\Delta^2 + L^2}}{L} - \frac{L}{L - L} \]
\[ P_{b} = \frac{4BEI\Delta}{I^3} \]
\[ P_{ps} = \frac{4P_{ps}\Delta}{I} \]

OK

Controls (OK < 310lbs)
Extruded Aluminum Post Input

- **Post Spacing, s =** 5 ft
- **Prestress Force, F_{ps} =** 255 lbs
- **Initial Cable Spacing, S_{o} =** 3.125 in
- **Unbraced Length = 42" - 1" - 3/8", L_{B} =** 40.625 in
- **Distributed Load, w =** 81.6 lb-in
- **Post Area, A_{p} =** 1.529 in²
- **Compressive Modulus of Elasticity, E =** 10100 ksi
- **Compression Section Modulus, S_{C} =** 0.836 in³
- **Moment of Inertia, I_x > I_y =** 0.940 in⁴
- **Clear Height of Shear Area, h =** 2.250 in
- **Thickness of Shear Area, t =** 0.250 in
- **Moment From Code Point Load, M_{pnt} =** 11.375 kip-in
- **Moment From Cable Prestress, M_{pstr} =** 16.834 kip-in

### Flat Elements Supported on Both Ends in Uniform Compression, 6061-T6 (ADM 2010 Section B5.4.2, Table 2-19 Part VI)

- **Slenderness, S =** 16.0
- **Allowable Stress, S_{S1} =** 21.2 ksi
- **Slenderness Limit, S_{1} =** 21
- **Allowable Stress, S_{1} < S_{2} =** 22.6 ksi
- **Slenderness Limit, S_{2} =** 33
- **Allowable Stress, S_{2} =** 36.3 ksi
- **Allowable Bending Stress, F_{b} =** 21.2 ksi
- **Allowable Moment, S_{C} * F_{b} =** 17.715 kip-in
- **Applied Moment, w*L_{B}^2/8 =** 16.834 kip-in

### Flexural Compression Closed Shapes Lateral Torsional Buckling 6061-T6 (ADM 2010 Section F3.1, Table 2-19 Part VI)

- **Slenderness, S =** 137.4
- **Allowable Stress, S_{S1} =** 7.63 ksi
- **Slenderness Limit, S_{1} =** 55
- **Allowable Stress, S_{1} < S_{2} =** 21.110 ksi
- **Slenderness Limit, S_{2} =** 1685
- **Allowable Stress, S_{2} =** 4.609 ksi
- **Allowable Bending Stress, F_{b} =** 21.1 ksi
- **Applied Bending Stress, F_{b} =** 20.145 ksi

### Deflection Check, \( \Delta_{MAX} = L_{B}/12 \) (ICC Report AC273)

- **Allowable Deflection, \( \Delta_{allow} = ** 3.385 in
- **Applied Deflection, P*L_{B}^3/3EI = \Delta_{applied} ** 0.600 in

### Shear in Elements, Gross Section 6061-T6 (ADM 2010 Table Section G.2, Table 2-19 Part VI)

- **Allowable Stress, S_{S1} =** 12.7 ksi
- **Slenderness Limit, S_{1} =** 35.3
- **Allowable Stress, S_{1} < S_{2} =** 14.8 ksi
- **Slenderness Limit, S_{2} =** 63.0
- **Allowable Stress, S_{2} =** 151.0 ksi
- **Allowable Shear Stress, F_s =** 13 ksi
- **Allowable Shear, A_{p} * F_s =** V_{allow} ** 19.418 kips
- **Applied Shear, P =** V_{applied} ** 1.658 kips
Extruded Aluminum Stair Handrail Connection Input

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Spacing, s</td>
<td>5 ft</td>
</tr>
<tr>
<td>Force, F</td>
<td>250 lbs</td>
</tr>
<tr>
<td>Moment Arm</td>
<td>2.750 in</td>
</tr>
<tr>
<td>Initial Cable Spacing, S₀</td>
<td>0.000 in</td>
</tr>
<tr>
<td>Unbraced Length, L₂</td>
<td>1.600 in</td>
</tr>
<tr>
<td>Post Area, Aₚ</td>
<td>0.531 in²</td>
</tr>
<tr>
<td>Compressive Modulus of Elasticity, E</td>
<td>10100 ksi</td>
</tr>
<tr>
<td>Compression Section Modulus, Sₓ</td>
<td>0.079 in³</td>
</tr>
<tr>
<td>Moment of Inertia, Iₓ</td>
<td>0.019 in⁴</td>
</tr>
<tr>
<td>Torsion Constant, J</td>
<td>0.076 in⁴</td>
</tr>
<tr>
<td>Moment From Railing, M</td>
<td>0.688 kip-in</td>
</tr>
</tbody>
</table>

Flat Elements Supported on Both Ends in Uniform Compression, 6061-T6 (ADM 2010 Section B5.4.2, Table 2-19 Part VI)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slenderness, S</td>
<td>12.0</td>
</tr>
<tr>
<td>Allowable Stress, Sₛ₁</td>
<td>21.2 ksi</td>
</tr>
<tr>
<td>Slenderness Limit, S₁</td>
<td>21</td>
</tr>
<tr>
<td>Allowable Stress, S₁&lt;Ş&lt;S₂</td>
<td>23.8 ksi</td>
</tr>
<tr>
<td>Slenderness Limit, S₂</td>
<td>33</td>
</tr>
<tr>
<td>Allowable Stress, S₂ŞŞ₂</td>
<td>48.3 ksi</td>
</tr>
<tr>
<td>Allowable Bending Stress, F_b</td>
<td>21.2 ksi</td>
</tr>
<tr>
<td>Allowable Moment, S_c*F_b = Mallow</td>
<td>1.670 kip-in</td>
</tr>
<tr>
<td>Applied Moment, M_applied</td>
<td>0.688 kip-in</td>
</tr>
</tbody>
</table>

Deflection Check, ΔMAX = L₈/12 (ICC Report AC273)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Deflection, Δallow</td>
<td>0.133 in</td>
</tr>
<tr>
<td>Applied Deflection, PLS²/3EI = Δapplied</td>
<td>0.002 in</td>
</tr>
</tbody>
</table>

Shear in Elements, Gross Section 6061-T6 (ADM 2010 Table Section G.2, Table 2-19 Part VI)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Stress, Sₛ₁</td>
<td>12.7 ksi</td>
</tr>
<tr>
<td>Slenderness Limit, S₁</td>
<td>35.3</td>
</tr>
<tr>
<td>Allowable Stress, S₁&lt;Ş&lt;S₂</td>
<td>15.2 ksi</td>
</tr>
<tr>
<td>Slenderness Limit, S₂</td>
<td>63.0</td>
</tr>
<tr>
<td>Allowable Stress, S₂ŞŞ₂</td>
<td>268.5 ksi</td>
</tr>
<tr>
<td>Allowable Shear Stress, Fₛ</td>
<td>13 ksi</td>
</tr>
<tr>
<td>Allowable Shear, Aₛ*Fₛ = Vallow</td>
<td>6.747 kips</td>
</tr>
<tr>
<td>Applied Shear, V_applied</td>
<td>0.250 kips</td>
</tr>
</tbody>
</table>

Fillt Weld Strength (ADM 2005 Section 7.3.2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filler Shear Ultimate Strength, Fₛₜ</td>
<td>17 ksi</td>
</tr>
<tr>
<td>Base Metal Strength, Fₛₜwb</td>
<td>21 ksi</td>
</tr>
<tr>
<td>Weld Filler Weld size, Sₑ</td>
<td>0.188 in</td>
</tr>
<tr>
<td>Weld Section Modulus, Sₑ</td>
<td>0.271 in³</td>
</tr>
<tr>
<td>Factor of Safety, νₑ</td>
<td>1.95</td>
</tr>
<tr>
<td>Allowable Weld Strength, Fₛₜ/νₑ</td>
<td>6.164 ksi</td>
</tr>
<tr>
<td>Applied Weld Stress, M/S = Fₛₜ</td>
<td>2.537 ksi</td>
</tr>
</tbody>
</table>

Shear Capacity of Screw (ADM 2010 J5.6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Ultimate Strength of Member in Contact with screw head, Fₜ₁</td>
<td>38 ksi</td>
</tr>
<tr>
<td>Thick. of Member in Contact with Screw, t₁</td>
<td>0.065 in</td>
</tr>
<tr>
<td>Tensile Ultimate Strength of Member Not in Contact with screw head, Fₜ₂</td>
<td>38 ksi</td>
</tr>
<tr>
<td>Thick. of Member Not in Contact with Screw, t₂</td>
<td>0.140 in</td>
</tr>
<tr>
<td>Nominal Shear Strength of Screw, Pₛₚ</td>
<td>2.363 kips</td>
</tr>
<tr>
<td>Screw Diameter, D</td>
<td>0.190 in</td>
</tr>
<tr>
<td>No. of Screws, n</td>
<td>2</td>
</tr>
<tr>
<td>Safety Factor, rs</td>
<td>3.00</td>
</tr>
<tr>
<td>Safety Factor, νₑ</td>
<td>1.95</td>
</tr>
<tr>
<td>Allowable Shear Stress, Vₐ</td>
<td>0.963 kips</td>
</tr>
<tr>
<td>Applied Shear, Vₐ</td>
<td>0.250 kips</td>
</tr>
</tbody>
</table>
### Extruded Aluminum Post Facia Mount Input

**Anchor Design Criteria**

- Applied Load At Top, \( P = 250 \) lbs
- Height of handrail point load, \( h_h = 42 \) in
- Height of decking, \( h_d = 1.5 \) in
- Height of beam, \( h_b = 9.25 \) in
- Height of top anchor, \( h_t = 2 \) in
- Height of bot anchor, \( h_{db} = 1.25 \) in
- Anchor bolt spacing, \( s = 6 \) in
- Unbraced Post Length, \( L_b = 45.5 \) in
- Lumber species = DF
- Thickness of joist = 3 in
- Simpson Holdown = DTT2Z
- Tension allowed, \( T_{allowed} = 2145 \) lbs

### Extruded Aluminum Post Facia Mount Output

**Anchor Calc**

- Tension applied per top bolt, \( T_t = 1819 \) lbs
- Tension applied per bottom bolt, \( T_b = 1569 \) lbs

\[
Tension \ max = 1819 \text{ lbs} \quad OK
\]
Distribute force T over 3" trib

\[ T/b = \frac{1.88}{3} = 0.628 \]

Bending load, \( M_a = \frac{Pb}{4} \cdot \frac{0.628(2)}{4} = 0.31 \text{ k}\text{f} \)

**Flexural Yielding/Rupture, \( M_a \):** (ADM Sect F.2)

\[ M_a = \frac{1}{2} \left( \frac{1}{6} \left( 3.0 \right) \left( \frac{3}{4} \right)^2 \right) \times 35 = 0.923 \text{ k}\text{f} \]

\[ M_a = 1.5 S_f F_f = 1.5 \left( \frac{1}{6} \times 3 \times \frac{3}{4} \right) \times 35 = 0.923 \text{ k}\text{f} \]

\[ M_a = \frac{1}{2} \left( \frac{1}{6} \left( 3.0 \right) \left( \frac{3}{4} \right)^2 \right) \times 35 = 0.923 \text{ k}\text{f} \]

\[ M_a / J_\ell = \frac{0.923}{1.0} / 0.568 = 0.568 \text{ k}\text{f} \]

\[ 1.00 / 1.95 = 0.514 \text{ k}\text{f} \]

**LTB, \( M_a \):** (ADM Sect F.4)

\[ \lambda = \frac{3.5}{b} \left( \frac{1.5}{C_b} \right)^{\frac{1}{3}} \left( \frac{1}{h_0} \right) = 30.5 < C_b = 65.7 \]

\[ M_a \left( 1 - \frac{1}{C_b} \right) + \frac{\pi^2 E A S}{C_b^2} = 0.933 \left( 1 - \frac{39.5}{65.7} \right) + \frac{\pi^2 (10,000)(20.5)(1/4)(3/4)}{(65.7)^2} \]

\[ = 0.502 \pm 0.184 \]

\[ = 0.614 \text{ k}\text{f} \]

\[ M_a / S_\ell = 0.614 / 1.0 = 0.614 \text{ k}\text{f} \]

\[ \Delta_{cr} = M_a / (M_a / S_\ell) = 0.31 / 0.614 \pm 0.74 < 1.0 \]

\[ O.K. \]
Compression on Post Elements

Distribute force \( T \) equally to each side:

\[
\begin{align*}
T_{1c} &= 0.92k \quad T_{2c} = 1.84/2 = 0.92k
\end{align*}
\]

Compression per Member Buckling (ADMA Sect E.2)

\[
\begin{align*}
\lambda_1 &= \frac{B_c - F_{cy}}{D_c} = \frac{39.4 - 35}{0.275} = 17.9; \quad \lambda_2 = 6.97 \\
\lambda &= 2.75 \cdot 2(\pi) = 22.7 \\
F_{c} &= \left( \frac{B_c - D_c\lambda}{D_c - \lambda_1} \right) \left( 0.85 - 0.15 \left( \frac{C_2 - \lambda}{C_2 - \lambda_1} \right) \right) \\
&= \left( \frac{39.4 - 2(2.75)}{0.275} \right) \left( 0.85 - 0.15 \left( \frac{6.7 - 17.9}{6.7 - 17.9} \right) \right) \\
&= (22.7) \left( 0.85 \right) \\
&= 19.96 \text{ ksi}
\end{align*}
\]

\[
\begin{align*}
P_{cc} &= F_{c}A_2 = 16.84(18.33) = 304 \text{ kN} \\
P_{cc}/A_2 &= 6.36/18.33 = 0.35k > 0.92k \checkmark \text{ ok}
\end{align*}
\]

Check Torsional and Flexural-Torsional Buckling (E.2.2)

\[
\lambda = \pi \sqrt{E/F_c} = \pi \sqrt{10100/204} = 22.1 < K_4/\lambda_i \text{ use above results}
\]

\[
\begin{align*}
F_{c} &= \pi \sqrt{E/F_c} = \pi \sqrt{10100/204} = 204 \text{ kN} \\
E &= 10100 \text{ kN/m} \\
C_w &= \frac{1}{5} \left( \frac{1}{18} \pi \right)^3 \left( \frac{275}{18} \right)^3 = 0.000821 \text{ in}^4 \\
K_2 &= 0.5 \\
L_2 &= 2 \text{ in} \\
G &= 3000 \text{ kN/m} \\
S &= \frac{3}{8} (2.75) (18) = 0.0014 \text{ in}^4 \\
I_c &= \frac{1}{2} (18)^3 / 12 = 0.00326 \text{ in}^4 \\
I_y &= \frac{1}{2} (18)^3 / 12 = 0.281 \text{ in}^4
\end{align*}
\]

Check Local Buckling (E.3.2)

\[
F_c: \quad \lambda \geq 14.74 < \lambda_i \quad (E.3.4.6)
\]

\[
\begin{align*}
\lambda_1 &= (B_p - F_{cy}) / D_p = (45 - 35) / 0.246 = 40.7 \\
\lambda_2 &= K_4 / D_p = 0.5 / 0.246 = 2.04 \\
\lambda_2 / \lambda_1 &= 0.25 < 0.9 \text{ Fe above yours}
\end{align*}
\]

Check Buckling of Member Buckling and Local Buckling (E.4.9)

No interaction \( \text{ w.r.t. } F_c \geq F_c \)