

References:	1. ASCE Specification for the Design of Cold-Formed Stainless Steel Structural Members 2. MARS Nonconformance #734 [ <a href="https://noncon.marsspaceport.com/noncons/view/1968">https://noncon.marsspaceport.com/noncons/view/1968</a> ]
Description:	ARE-EDG-3M-AA-24-LED-C-UL-SV-AMB-F Adjustment Arm Bolt Support Calculation
Engineer:	M. Stevens
Date:	5/15/2014

#### Problem:

MARS recently experienced an adjustment arm failure one of the installed Cree ARE-EDG-3M-AA-24-LED-C-UL-SV-AMB-F LED light fixtures that resulted in the fixture falling from the light pole. Engineering would like to add additional structural support to each of these fixtures to prevent future failures.

#### Assumptions/ Inputs:

- 1) The weight of the fixture ( $W_f$ ) is 50 lb.
- 2) The top face of the fixture is a flat plate with a surface area ( $A_s$ ) of 641.2 in<sup>2</sup>
- 3) The drag coefficient ( $C_d$ ) of a wind load acting on a short flat plate is 1.4
- 4) There are three primary forces acting on the top surface of the flat plate:
  - a.  $F_{\text{weight}}$  = force due to weight of the fixture under acceleration due to gravity
  - b.  $F_{\text{wind}}$  = force due to maximum design wind load acting uniformly on top plate surface
  - c.  $F_{\text{blast}}$  = force due to rocket blast wave acting 45° downward on the top plate surface
- 5) The aforementioned forces act as a single combined point load on the end of the plate ( $L_{\text{plate}} = 24.1$  in.)
- 6) The blast wave exerts a vertical downward pressure ( $P_{\text{blast}}$ ) of 1 psi on the closest fixture from the liftoff point
- 7) Wind pressure ( $P_{\text{wind}}$ ) for a wind load of 120 mph is assumed to be 0.1 psi according to the Beaufort Wind Scale
- 8) Only shear stress is considered in the bolt failure analysis since the bolt hex will be flush with the fixture

#### Calculations:

##### Wind force:

$$F_{\text{wind}} = (A_s) \cdot (P_{\text{wind}}) \cdot (C_d)$$

$$= (641.2 \text{ in}^2) \cdot (0.1 \text{ lb}_f/\text{in}^2) \cdot (1.4) = 89.77 \text{ lb}_f$$

##### Blast force:

$$F_{\text{blast}} = \sin(\theta) \cdot (A_s) \cdot (P_{\text{blast}})$$

$$= \sin(45^\circ) \cdot (641.2 \text{ in}^2) \cdot (1 \text{ lb}_f/\text{in}^2) = 453.4 \text{ lb}_f$$

##### Moment about point J:

$$\Sigma M_J = (F_{\text{weight}} + F_{\text{wind}} + F_{\text{blast}}) \cdot (L_{\text{plate}})$$

$$= (50 \text{ lb}_f + 89.77 \text{ lb}_f + 453.4 \text{ lb}_f) \cdot (24.1 \text{ in}) = 14295.4 \text{ in} \cdot \text{lb}_f$$

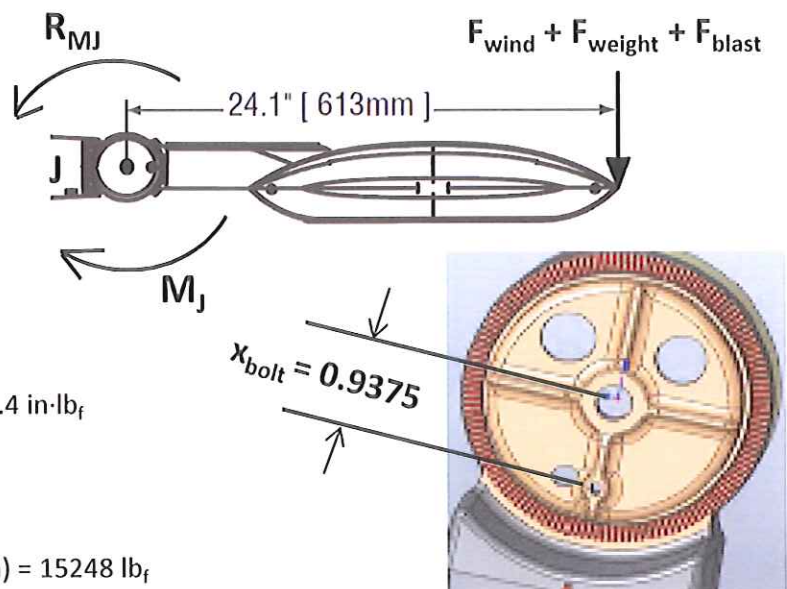
##### Reaction moment at distance $x_{\text{bolt}}$ from point J:

$$M_J = 14295.4 \text{ in} \cdot \text{lb}_f = R_{MJ} = (F_{\text{bolt}}) \cdot (x_{\text{bolt}})$$

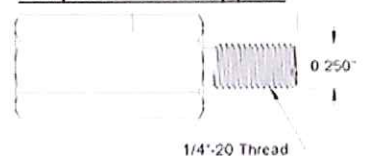
$$\Rightarrow F_{\text{bolt}} = (R_{MJ}) / (x_{\text{bolt}}) = (14295.4 \text{ in} \cdot \text{lb}_f) / (0.9375 \text{ in}) = 15248 \text{ lb}_f$$

$$\tau_{\text{max}} = (F_{\text{bolt}}) / (A_{\text{bolt}}), \text{ where } A_{\text{bolt}} = \text{cross-sec. area of } 1/4" \text{ bolt} = 0.049 \text{ in}^2$$

$$\text{Therefore, } \tau_{\text{max}} = (15248 \text{ lb}_f) / (0.049 \text{ in}^2) = 311192.381 \text{ lb}_f/\text{in}^2 = 311.2 \text{ ksi}$$



Proposed bolt support



#### Results/ Conclusion:

Per Table 6 (Nominal Shear and Tensile Stresses for Stainless Steel Bolts) on page 25 of Reference #1, the nominal shear stress for an ASTM A276-85a cold-finished 316 stainless steel bolt with threads in the shear plane is 40.5 ksi, which is well under the maximum expected shear stress in the fixture.

lows:

$$\phi = \text{resistance factor given in Table 6} \\ P_n = A_b F \quad (5.3.4-1)$$

where:

$A_b$  = gross cross-sectional area of bolt; and  
 $F$  is given by  $F_u$  or  $F_m$  in Table 6.

product code approvals, or product specifications and/or product literature.

When bolts are subjected to a combination of shear and tension, the required tension strength shall not exceed the design strength,  $\phi P_n$  based on  $\phi = 0.75$  and  $P_n = A_b F'_{et}$ , in which  $F'_{et}$  is determined as follows:

1. Threads in shear plane:

$$F'_{et} = 1.25 F_{et} - 2.4 f_u \leq F_{et} \quad (5.3.4-2)$$

TABLE 6. Nominal Shear and Tensile Stresses for Stainless Steel Bolts

Type of stainless steels	Diameter $d$ inch (mm)	Nominal shear stress $F_{nv}$ $\phi = 0.65$		Nominal tensile stress <sup>g</sup> $F_{tu}$ $\phi = 0.75$ ksi (MPa)
		No threads in shear plane	Threads in shear plane <sup>f</sup>	
		ksi (MPa)	ksi (MPa)	
201 <sup>a</sup>	all	45.0 (310.8)	33.7 (232.4)	56.0 (386.1)
304, 316 <sup>b</sup>	all	45.0	33.7	56.0
304, 316 <sup>c</sup>	$\leq 1/2$ (12.7)	54.0 (372.3)	40.5 (279.2)	67.5 (465.4)
	$> 1/2$ (12.7)	45 (310.3)	33.7 (232.4)	56.0 (386.1)
304, 316 <sup>d</sup>	$\leq 3/4$ (19.1)	75.0 (517.1)	56.2 (387.5)	93.7 (646.1)
430 <sup>e</sup>	all	36.0 (248.2)	27.0 (186.2)	45.0 (310.3)
430 <sup>f</sup>	$1/4 \leq d \leq 1-1/2$ (6.4 $\leq d \leq 38.1$ )	42.0 (289.6)	31.5 (217.2)	52.5 (361.9)
304, 316 <sup>e</sup>	$1/4 \leq d \leq 1-1/2$ (6.4 $\leq d \leq 38.1$ )	42.0 (289.6)	31.5 (217.2)	52.5 (362.0)
304, 316 <sup>f</sup>	$1/4 \leq d \leq 5/8$ (6.4 $\leq d \leq 15.9$ )	57.0 (393.0)	42.8 (295.1)	71.2 (490.9)
	$3/4 \leq d \leq 1-1/2$ (19.1 $\leq d \leq 38.1$ )	48.0 (331.0)	36.0 (248.2)	60.0 (413.7)

<sup>a</sup> Condition A in ASTM A276-85a, hot- or cold-finished.

<sup>b</sup> Condition A in ASTM A276-85a, hot-finished and Class 1 (solution-treated) in ASTM A193/A193M-86.

<sup>c</sup> Condition A in ASTM A276-85a, cold-finished.

<sup>d</sup> Condition B (cold-worked) in ASTM A276-85a, cold-finished and Class 2 (solution-treated and strain-hardened) in ASTM A193/A193M-86.

<sup>e</sup> Condition A in ASTM F593-86a, machined from annealed or solution-annealed stock, or hot-formed and solution-annealed. The minimum tensile strength is based on tests on the machined specimen.

<sup>f</sup> Condition CW in ASTM F593-86a, headed and rolled from annealed stock thus acquiring degree of cold work. Sizes 3/4 in. (19.05 mm) diameter and larger may be hot-worked. The minimum tensile strength is based on tests on the machined specimen.

<sup>g</sup> No reduction of nominal stress given in Table 6 is required for  $d \leq 1/2$  in. (12.7 mm). For  $d > 1/2$  in. (12.7 mm) given value shall be reduced to  $0.9F_{nv}$  for nominal shear stress, and  $0.9F_{tu}$  for nominal tensile stress.