Texas A&M Transportation Institute
3135 TAMU
College Station, TX 77843-3135
979-317-2707
Fax: 979-845-6107
http://tti.tamu.edu/crashtesting

PROFESSIONAL RECOMMENDATION MEMORANDUM

Project Name: **Engineering Support Services and Recommendations for Roadside Safety Issues/Problems for Member States**

Sponsor: **Roadside Safety Pooled Fund**

Task 20-08: **Utah Sign Support Bracket Sacrificial Pin Design for 115 mph Wind Speed**

DATE: **April 13, 2021**

FROM: **William Williams, P.E.**, Associate Research Engineer,
Jilong Cui, Graduate Student Worker (PhD Candidate)

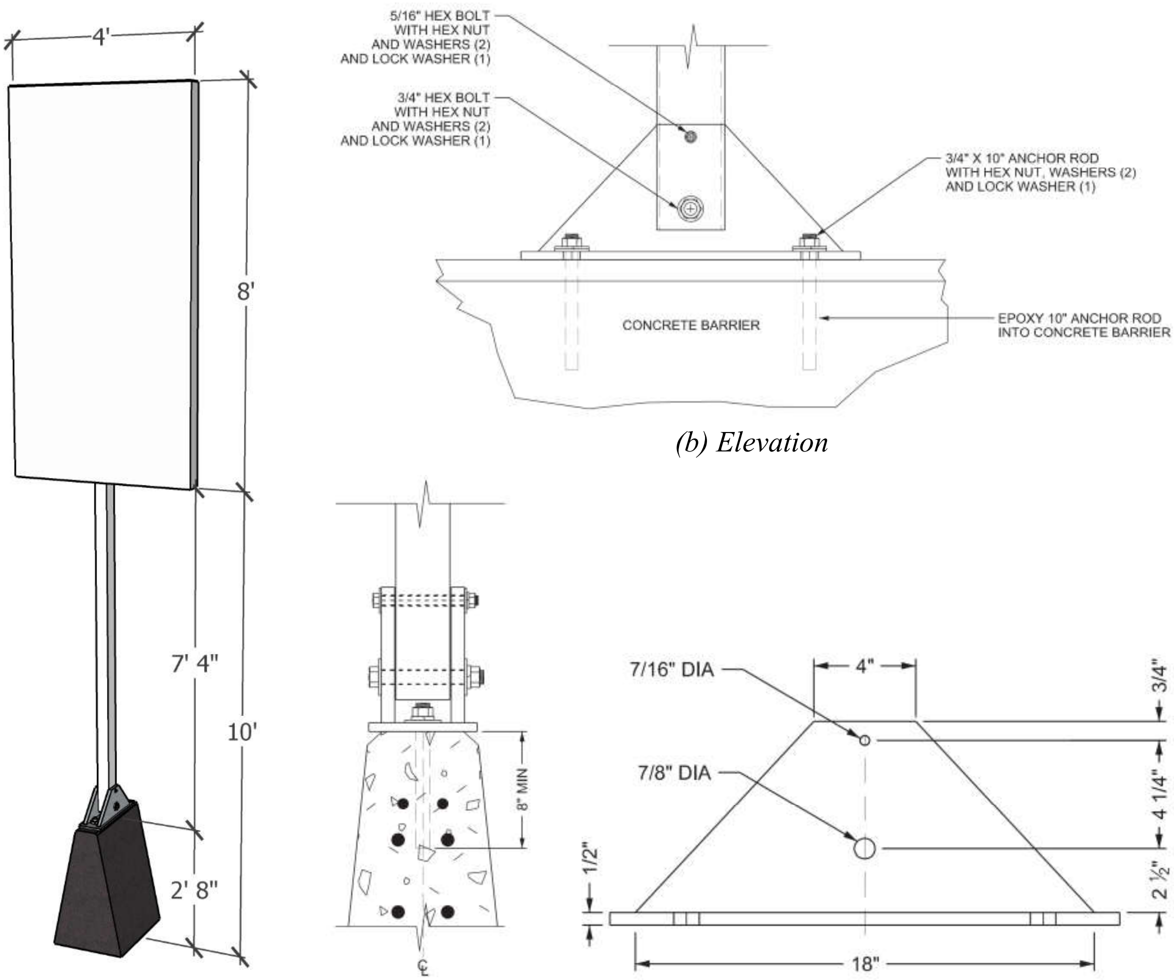
FOR MORE INFORMATION:
Name: William Williams
Phone: 979-317-2707
Email: w-williams@tti.tamu.edu

Overview/Problem Statement

Utah Department of Transportation is having an issue with the Bracket and Sacrificial Pin Sign Base for the signpost system due to the wind loads on the sign and sacrificial pin. The sacrificial pin is found to be shearing during normal/typical wind events in Utah. To address such concerns, UDOT has asked to increase the size or grade of the sacrificial pin to allow for a greater wind load capacity while maintaining crashworthiness. UDOT is also asked a use of rubber bumper underneath the post to reduce the chance of secondary damage after the signpost activated while not affecting the crashworthiness of the system. The purpose of this research is to analyze the sacrificial pin for 115 mph wind speed using a 4’x8’ signage area and design a new pin to resist this wind loading condition. In addition, based on information provided to us, TTI has provided a professional opinion on the use of the rubber bumper as shown herein.

Analysis & Design Approach

The details of the signpost system are shown in Figure 1. The wind load on the rectangular sign panel (4'x8') is calculated with a design wind speed of 115 mph as specified by AASHTO LRFD 2017 for Utah state. The reaction forces on the bolts induced by the wind load are shown in (Figure 2).



(a) Overview *(b) Elevation* *(c) Side-view* *(d) Pivot sign base*

Figure 1. Schematic of Signpost System

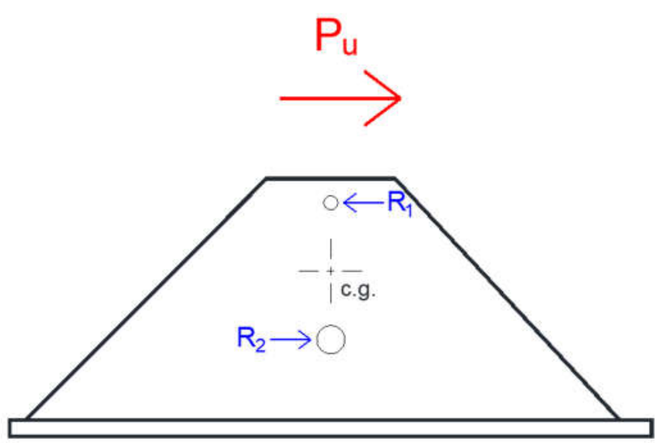


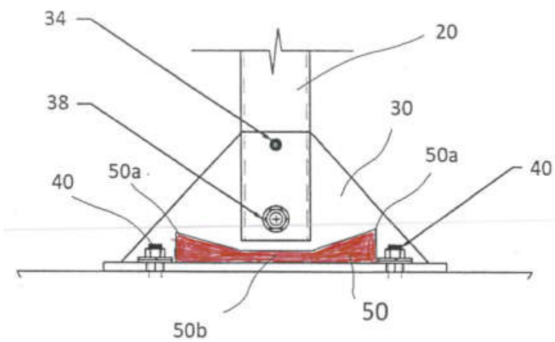
Figure 2. Bolt Reactions Against Wind Load

The capacity of the lower bracket bolt was found to be sufficient to resist the design wind load. However the sacrificial pin, as it is currently used by Utah DOT, was found to be inadequate for the design wind speed of 115 mph. To resist the required wind load, a 5/8 in. diameter A325 bolt is recommended for the sacrificial pin. Additionally, a vertical slot for the upper bolt (sacrificial pin) proposed by UDOT, as shown in Figure 3, would be beneficial by allowing an easier installation and maintenance while ensuring only the lower bolt carrying the weight of the signpost where the sacrificial pin is only for the shear resistance. Please refer to the calculations attached to this memorandum for additional information.

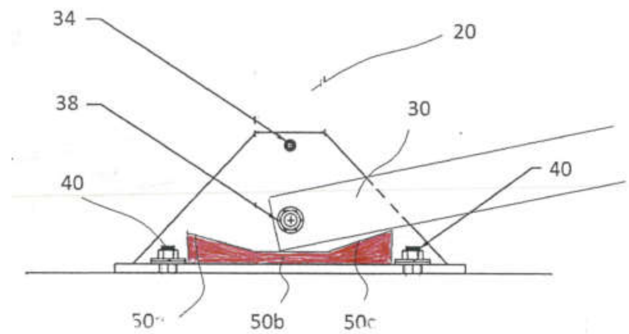
Figure 3. Vertical Slot for Sacrificial Pin

Utilization of Rubber Bumper on Signpost Bracket. to avoid secondary damage after the signpost activated

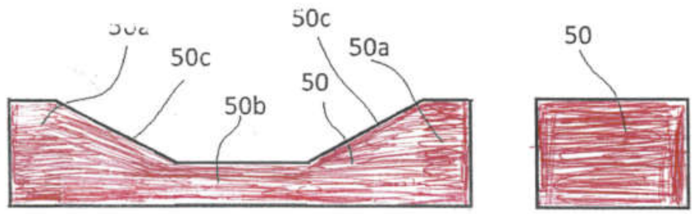
A rubber bumper on the signpost bracket is proposed by Utah DOT. The purpose of this rubber bumper is to improve safety of the sign from secondary impacts after the signpost has been struck and activated. The use of rubber bumper (solid ballistic rubber) underneath the post will elevated the sign at an angle above the barrier after the signpost is activated from a vehicle impact. The rubber bumper that UDOT is currently proposing is shown in Figure 4. Figure 5 shows photos when the base of the sign and signpost is activated and is supported by the ballistic rubber bumper. As shown in Figure 5, it is our opinion that the use of the rubber bumper would enhance the overall safety performance of the sign and signpost from possible secondary impacts (instead of the sign and signpost laying horizontal on top of the barrier). Please refer to Figure 5 for additional information.



(a) Bumper placed underneath signpost



(b) After signpost activated



(c) Side view of rubber bumper

Figure 4. Rubber Bumper Diagram

(a) Rubber bumper after signpost lying down

(b) Activated signpost with rubber bumper

Figure 5. Utilization of Rubber Bumper

Summary and Recommendations

Based on the results of our calculation: It is recommended that a 5/8” diameter A325 bolt be used as the the sacrifical pin in the bracket to resist the 115 mph design wind speed. In addition, the use of the rubber bumper on the bracket is acceptable and should not interfere or reduce the safety perfoamce of the sign and signpost design as showns and described herein. Please refer to the calculations attached to this report for additional information.

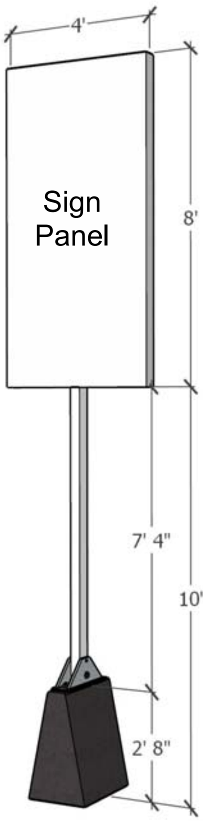
Appendix.

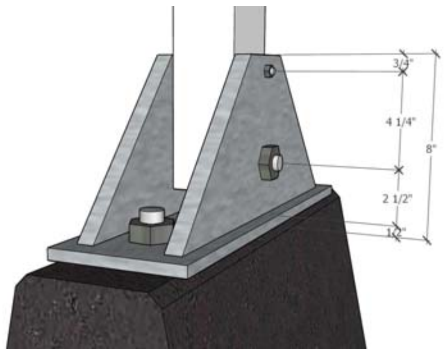
Calculation Worksheet

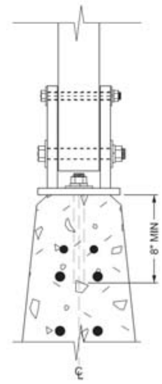
Texas A&M Transportation Institute

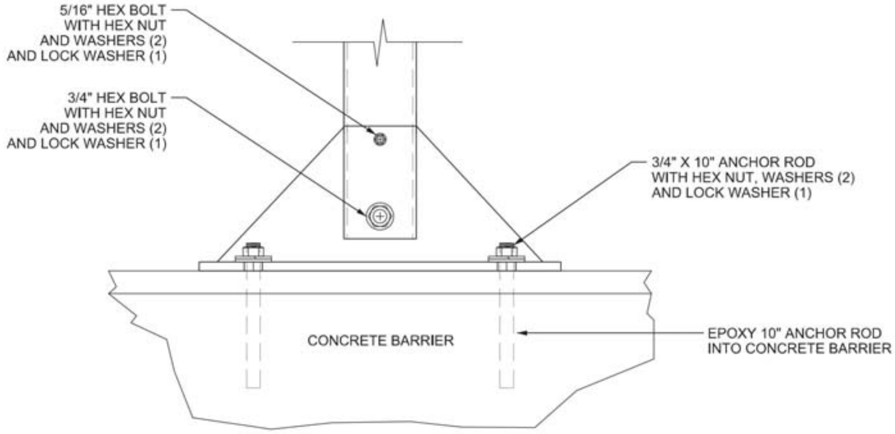
SUBJECT:
Professional Opinion 20-08 – Utah Sign Support Bracket Sacrificial Pin Design for 115 mph Wind Speed

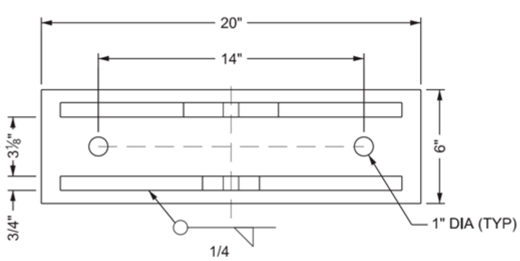
The presented worksheet calculates the force on the support pins of a sign panel system. An overview of the sign panel configuration and the support bracket details are presented in the following. Two different sized hex bolts are used at the bottom of the sign post to support the sign panel. The force on the bolts induced by the wind load on the panel is worked out.



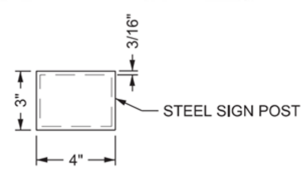




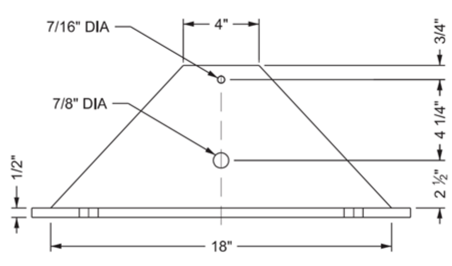




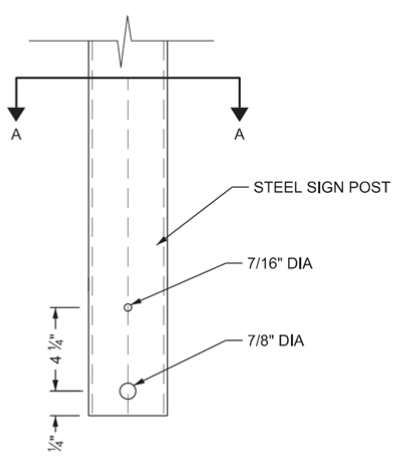
TOP VIEW



SECTION A-A



SIDE VIEW



Notes:
1. USE 32 SQ FT MAXIMUM SIGN PANEL AREA.

2. USE SIGN BASE IN MEDIAN APPLICATIONS ONLY, WITH MINIMUM SHOULDER WIDTH OF 4 FT AND MINIMUM BARRIER HEIGHT OF 32 INCH.

3. REFER TO STD DWG SN 2B FOR SIGN MOUNTING HEIGHT AND WIDTH REQUIREMENTS.

4. POST LENGTH DERTEMINED BY SIGN SIZE.

5. USE ASTM A36 STEEL FOR PIVOT SIGN BASE.

6.MEET ASTM A 123 GALVANIZING AFTER FABRICATION IS COMPLETE.

7. STEEL SIGN POST TO MEET STANDARD SPECIFICATION 02891.

8. USE BOLTS, NUTS AND WASHERS CONFORMING TO ASTM F3125, GRADE A325.

9. DURING INSTALLATION, IF REBAR IS ENCOUNDTERED, ADJUST THE BRACKET LOCATION LONGITUDINALLY. FILL ANY UNUSED HOLES WITH EPOXY.

1. General Information and Input

<u>*Geometry:*</u>

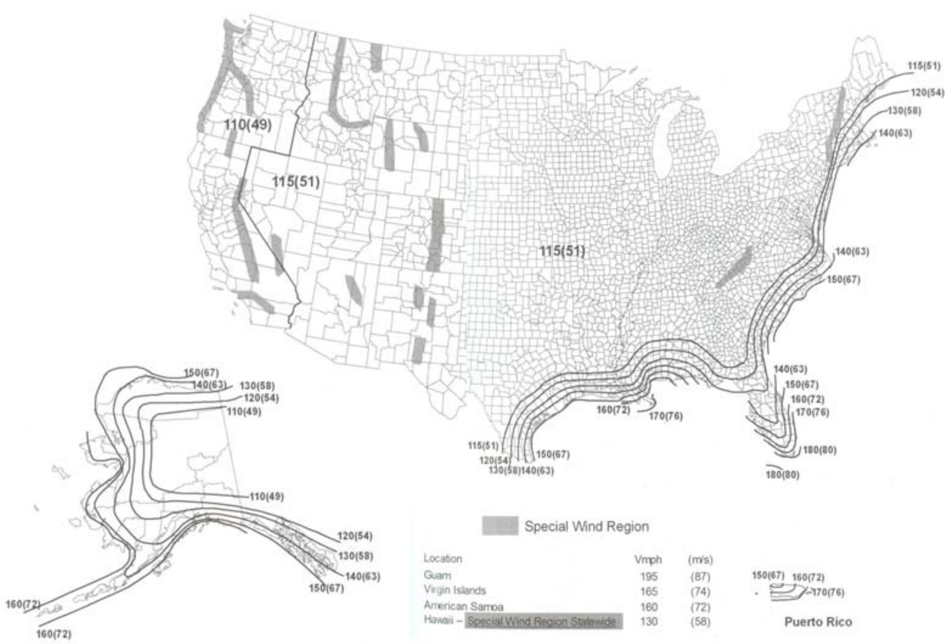
$H_{total} := 18\ ft$	*Distance from top of sign panel to ground*
$H_{barrier} := 32\ in$	*Height of concrete barrier*
$H_{panel} := 8\ ft$	*Height of sign panel*
$B_{panel} := 4\ ft$	*Width of sign panel*
$d_{bottom} := 3\ in$	*Distnace from center of bottom bolt to pivot base*
$s_{bolt} := 4.25\ in$	*Bolt spacing*

<u>*Bolt size (Grade A325):*</u>

$d_{bolt\_top} := \frac{5}{16}\ in$	*Top bolt diameter*
$d_{bolt\_bot} := \frac{3}{4}\ in$	*Bottom bolt diameter*

<u>*Design wind speed:*</u>

$V := 115\ mph$	*Design wind speed per AASHTO LRFD 3.8.1.1.2*



Notes:

1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 Years).

Figure 3.8.1.1.2-1—Design Wind Speed, *V*, in mph (m/s)

*(*Figure taken from AASHTO LRFD)*

2. Wind load on sign panel (AASHTO LRFD)

Wind pressure on sign panel:

$V = 115\ mph$ — *Design 3-second gust wind speed specified in article Table 3.8.1.1.2-1 (mph)*

$K_z := 1$ — *Pressure exposure and elevation coefficien specified in article Table C3.8.1.2.1-1*

$G := 0.85$ — *Gust effect factor specified in article Table 3.8.1.2.1-1*

$C_D := 1.2$ — *Drag coefficient specified in article Table 3.8.1.2.1-2*

$$P_z := 2.56 \cdot 10^{-6} \cdot V^2 \cdot K_z \cdot G \cdot C_D \cdot \left(\frac{1}{mph^2} \cdot ksf \right) = 0.035\ ksf$$ *Equation 3.8.1.2.1-1*

Resultant wind load on sign panel:

$$P_u := P_z \cdot H_{panel} \cdot B_{panel} = 1.105\ kip$$

Table 3.8.1.1.2-1—Design 3-Second Gust Wind Speed for Different Load Combinations, *V*

Load Combination	3-Second Gust Wind Speed (mph), *V*
Strength III	Wind speed taken from Figure 3.8.1.1.2-1
Strength V	80
Service I	70
Service IV	0.75 of the speed used for the Strength III limit state

Table C3.8.1.2.1-1—Pressure Exposure and Elevation Coefficients, K_Z

Structure Height, *Z* (ft)	Wind Exposure Category B	Wind Exposure Category C	Wind Exposure Category D
$\leq$ 33	0.71	1.00	1.15
40	0.75	1.05	1.20
50	0.81	1.10	1.25
60	0.85	1.14	1.29
70	0.89	1.18	1.32
80	0.92	1.21	1.35
90	0.95	1.24	1.38
100	0.98	1.27	1.41
120	1.03	1.32	1.45
140	1.07	1.36	1.49
160	1.11	1.40	1.52
180	1.15	1.43	1.55
200	1.18	1.46	1.58
250	1.24	1.52	1.63
300	1.30	1.57	1.68

Table 3.8.1.2.1-1—Gust Effect Factor, *G*

Structure Type	Gust Effect Factor, *G*
Sound Barriers	0.85
All other structures	1.00

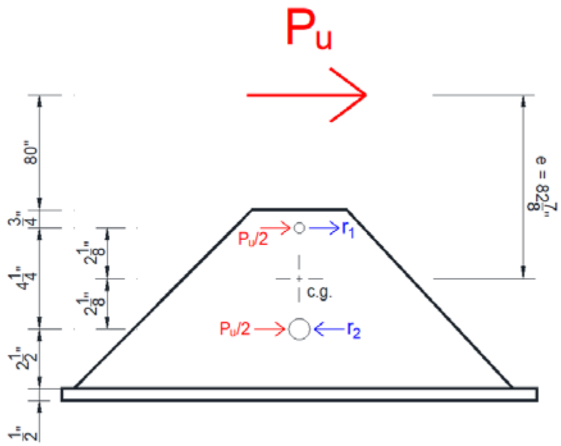
Table 3.8.1.2.1-2—Drag Coefficient, C_D

Component		Drag Coefficient, C_D Windward	Leeward
I-Girder and Box-Girder Bridge Superstructures		1.3	N/A
Trusses, Columns, and Arches	Sharp-Edged Member	2.0	1.0
	Round Member	1.0	0.5
Bridge Substructure		1.6	N/A
Sound Barriers		1.2	N/A

*(*Tables taken from AASHTO LRFD)*

3. Bolt shear force due to wind load (elastic method)

Assume the resultant wind load is acting as a point load at the center of the sign panel, the following eccentrically loaded bolt group configuration can be drawn.



Total load acting on bolt group:

$$P_u = 1.105\ kip$$

Load eccentricity:

$$e := H_{total} - H_{panel} - H_{barrier} - d_{bottom} - \frac{s_{bolt}}{2}$$

$H_{total} = 18\ ft$; $H_{panel} = 8\ ft$; $H_{barrier} = 32\ in$

$d_{bottom} = 3\ in$; $s_{bolt} = 4.25\ in$

$$e = 82.875\ in$$

Force applied on bolt by direct load:

$$r_{pxu} := \frac{P_u}{2} = 0.553\ kip$$ *Horizontal direction*

$$r_{pyu} := 0$$ *Vertical direction*

Force applied on bolt by eccentric load (moment):

Distance from center of bolt to center of gravity:

$x_{top} := 0\ in$ $\quad y_{top} := \frac{s_{bolt}}{2} = 2.125\ in$ *Top bolt*

$x_{bot} := 0\ in$ $\quad y_{bot} := \frac{s_{bolt}}{2} = 2.125\ in$ *Bottom bolt*

Polar moment of inertia of bolt group:

$$I_x := y_{top}^2 + y_{bot}^2 = 9.031\ \frac{in^4}{in^2}$$

$$I_y := x_{top}^2 + x_{bot}^2 = 0\ \frac{in^4}{in^2}$$

$$I_p := I_x + I_y = 9.031\ \frac{in^4}{in^2}$$

Resultant force on bolt due to eccentric load:

$r_{mxu\_top} := \frac{P_u \cdot e \cdot y_{top}}{I_p} = 21.55\ kip$ $\quad r_{myu\_top} := \frac{P_u \cdot e \cdot x_{top}}{I_p} = 0\ kip$ *Top bolt*

$r_{mxu\_bot} := \frac{P_u \cdot e \cdot y_{bot}}{I_p} = 21.55\ kip$ $\quad r_{myu\_bot} := \frac{P_u \cdot e \cdot x_{bot}}{I_p} = 0\ kip$ *Bottom bolt*

Total shear force on the bolts:

$$r_{u\_top} := \sqrt{\left(r_{pxu}+r_{mxu\_top}\right)^2+\left(r_{pyu}+r_{myu\_top}\right)^2} = 22.1\ kip$$ *Top bolt*

$$r_{u\_bot} := \sqrt{\left(r_{pxu}-r_{mxu\_bot}\right)^2+\left(r_{pyu}+r_{myu\_bot}\right)^2} = 21\ kip$$ *Bottom bolt*

4. Check bolt capacity

Load resistant factor for shear strength:

$\phi := 0.75$ *AISC J3.2*

Shear strength of bolt (AISC Table J3.2):

$F_{nv} := 48\ ksi$ *Nominal shear stress of A325 bolts, when **threads are not excluded** from shear planes*

Nominal area of bolt:

$d_{bolt\_top} = 0.3125\ in$; $d_{bolt\_bot} = 0.75\ in$

$$A_{b\_top} := \frac{\pi \cdot d_{bolt\_top}^2}{4} = 0.077\ in^2$$ *Top bolt*

$$A_{b\_bot} := \frac{\pi \cdot d_{bolt\_bot}^2}{4} = 0.442\ in^2$$ *Bottom bolt*

Nominal shear strength of bolt (double shear):

$R_{n\_top\_n} := 2 \cdot F_{nv} \cdot A_{b\_top} = 7.36\ kip$ *Top bolt*

$R_{n\_bot\_n} := 2 \cdot F_{nv} \cdot A_{b\_bot} = 42.41\ kip$ *Bottom bolt*

Design shear strength of bolt (double shear):

$\phi \cdot R_{n\_top\_n} = 5.52\ kip$	Shear force on top bolt	$r_{u\_top} = 22.1\ kip$	**(N.G.)**
$\phi \cdot R_{n\_bot\_n} = 31.81\ kip$	Shear force on bottom bolt	$r_{u\_bot} = 21\ kip$	**(O.K.)**

Recommended bolt size (A325):

$$d := \sqrt{2 \cdot \frac{r_{u\_top}}{\phi \cdot F_{nv} \cdot \pi}} = 0.625\ in$$

Therefore, a A325 bolt that has bigger or equal to **0.625 in. (5/8 in.) diameter** is recommened.