

STRUCTURAL CALCULATIONS

for

LAGUNA WOODS VILLAGE EXISTING CARPORT STRUCTURE SOLAR PV PROJECT FEASIBILITY STUDY

Prepared By:

NS Structural Engineering, Inc.

May 20, 2016





Client: Princeton Engineering
Project: Johnson Controls, Inc.: Laguna Woods Village
Existing Carport Struct. Feasibility Study

Sheet 1
Job no _____
Date 5/20/2016
Engineer PD

Site Address

Laguna Woods Carport
24351 El Toro Road
Laguna Woods, CA 92637

Building Code

2013 California Building Code
ASCE 07-10

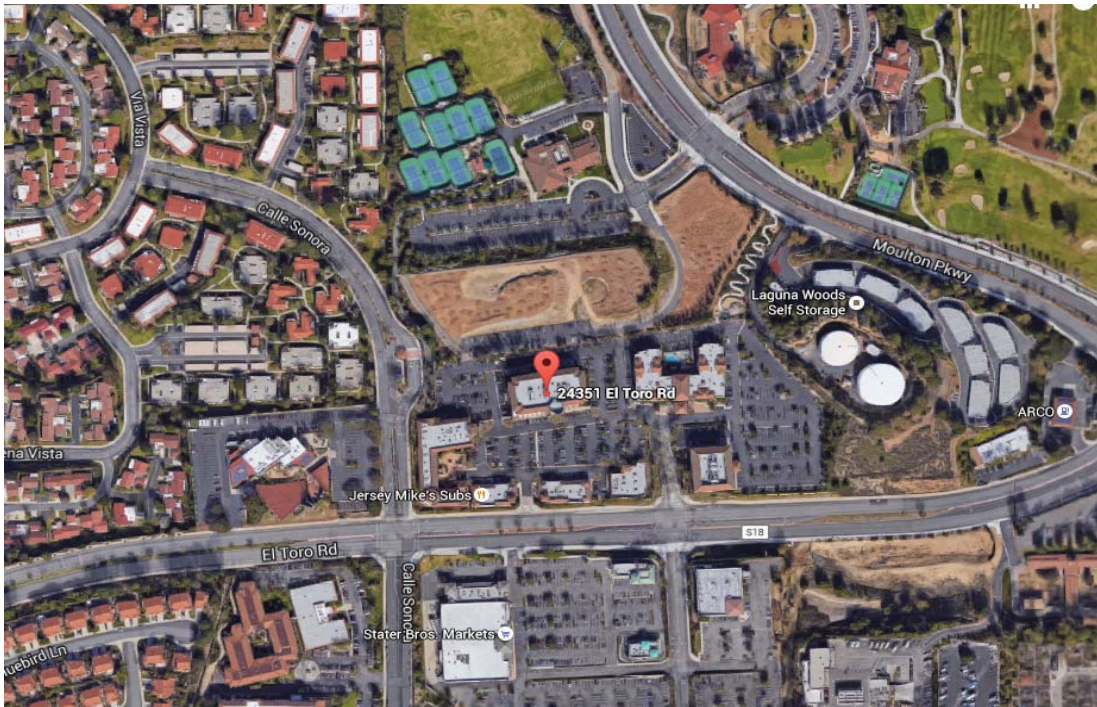
Site Specifications

Wind Speed, V 110 mph
Exposure C
 S_{DS} 1.00

Load Combination

1.4D
1.2D + 1.6L_r
1.2D + 1.0W + 0.5L_r
0.9D + 1.0W
(1.2 + 0.2S_{DS})D + E
(0.9 - 0.2S_{DS})D + E

Site Map





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Sheet 2
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Load Criteria

Dead Load	Existing Metal Deck	2.5 psf
	New PV Panel System	2.5 psf
	Misc	1 psf
	Total	6 psf
Roof Live Load		20 psf
Wind Load Roof, WL		-22.3 psf (LRFD) See "Wind Design" section
Seismic Parameter		

USGS Design Maps Summary Report

User-Specified Input

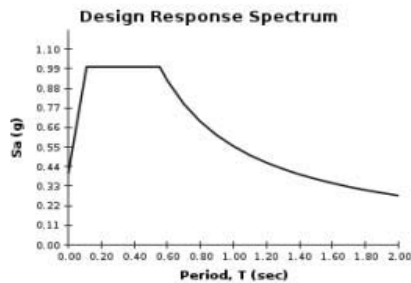
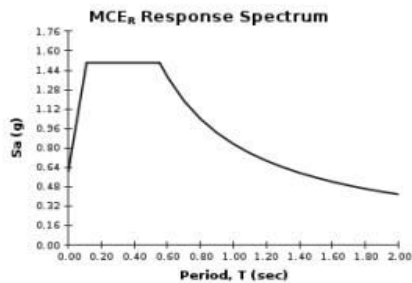
Report Title Laguna Woods
 Sun May 15, 2016 19:07:00 UTC
Building Code Reference Document 2012 International Building Code
 (which utilizes USGS hazard data available in 2008)
Site Coordinates 33.60924°N, 117.73079°W
Site Soil Classification Site Class D – "Stiff Soil"
Risk Category I/II/III



USGS-Provided Output

$S_2 = 1.501\text{ g}$ $S_{M5} = 1.501\text{ g}$ $S_{05} = 1.001\text{ g}$
 $S_1 = 0.555\text{ g}$ $S_{M1} = 0.832\text{ g}$ $S_{01} = 0.555\text{ g}$

For information on how the S5 and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.



Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.



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Sheet 3
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Wind Analysis (Directional Procedure)

2013 CBC Chapter 16, ASCE 7-10 Chapter 27

Wind Design Procedure

Basic Wind Speed, V	110	mph
Risk Category	I	
Exposure Category	C	
Wind directionality Factor, K_d	0.85	
Velocity Press. Exp. Coeff., K_z	0.85	
Topographical Factor, K_{zt}	1	
Gust Effect Factor, G	0.85	
Net Pressure Coefficient, C_N	-1.2	*Max for all case *Obstructed wind flow *Roof angle = 0 deg.
Velocity Pressure, q_z (psf)	21.9	psf
Net Design Pressure on Monoslope roof, p	-22.3	psf (LRFD)



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Seismic Lateral

System	Steel Ordinary Cantilever Column System
Response Modification Coeff., R	1 1/4
Overstrength Factor, Ω	1 1/4
Deflection Amplification Factor, C_d	1 1/4
Importance Factor, I_E	1
Seismic Response Coeff., C_s	0.8 *W (Eqn 12.8-2)

CANTILEVER COLUMN

3 1/2" ϕ STD PIPE COL
H = 8'

$$V = 0.8W,$$

$$W = \frac{6 \text{ PSF} \times 20' \times 60.3'}{1000} = 7.2 \text{ K}$$

$$V = 0.8 \times 7.2 = 5.8 \text{ K}$$

$$F = \frac{5.8 \text{ K}}{8 \text{ columns}} = 0.725 \text{ K/column}$$

$$M = 0.725 \times 8' = 5.8 \text{ K}'$$

$$= 70 \text{ K}''$$

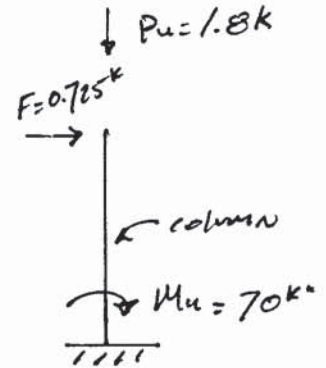
$$P_u = (1.2 + 0.2 S_{DS}) D = 1.8 \text{ K}$$

$$\phi M_n = 95 \text{ K}'' > 70 \text{ K}'' , \text{ ok}$$

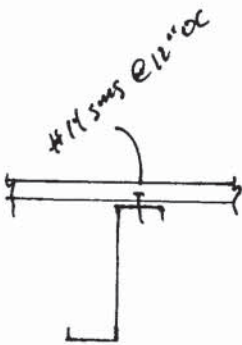
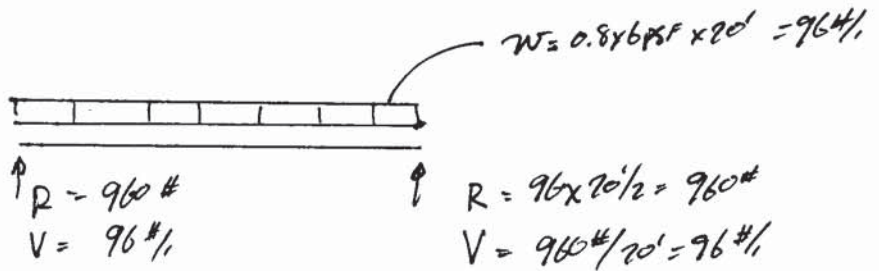
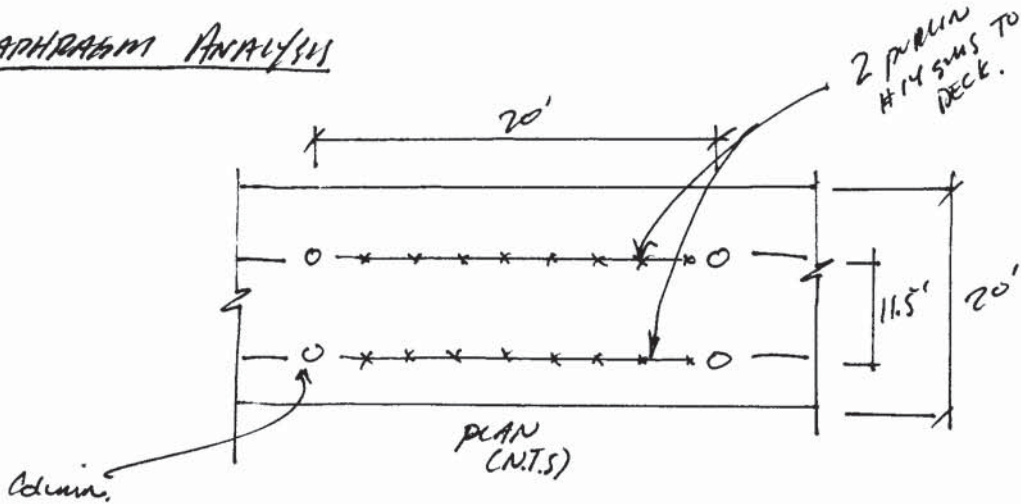
$$\phi P_n = 60.6 \text{ K} > 1.8 \text{ K} , \text{ ok}$$

COMBINED STRESS U

$$U = \frac{1.8}{2 \times 60.6} + \frac{70}{95} = 0.75 < 1.0, \text{ ok}$$



DIAPHRAGM ANALYSIS



$$M_u = 96 \times \frac{20^2}{6} = 4800 \# \cdot \text{ft}$$

$$\text{CHORD FORCE} = \frac{4800 \# \cdot \text{ft}}{11.5'} = 417 \#$$

FLANGE AREA (2" PURLIN)

$$A = 3.5 \times 0.1 = 0.35 \#$$

$$\phi P_n = 0.9 \times 0.35 \times 50 \text{ ksi} = 15.8 \text{ kips} > 417 \#, \text{ OK}$$

CONN. #14 sm's @ 12" OC. $\phi V_n = 1.5 \times 203 = 305 \#/\text{sm's}$

∴ $2 \times 305 = 610 \# > V_u = 96 \#/\text{ft}, \text{ OK}$

PURLIN CONN. PL - 6" x 3/16"

$$M_u = 960 \# \times 1.5" = 1440 \# \cdot \text{in}, R_{e\&D} z = 0.044$$

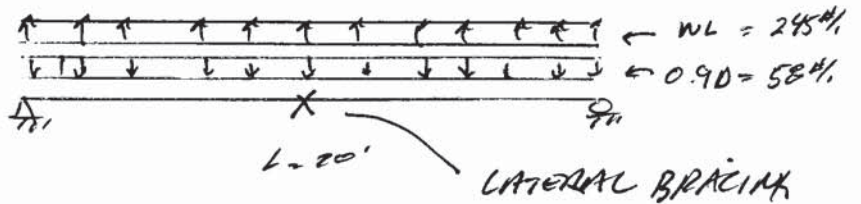
$$R_{e\&D} t = \sqrt{\frac{4 \times 0.044}{6}} = 0.17" < 3/16", \text{ OK}$$



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CHECK (F) "2" BEAM FOR WIND UPLIFT. (CASE 1 w/o STORAGE)
 GOVN. LOAD COMB. $0.9D + WL$



$$\left. \begin{aligned} w_{wl} &= 22.8 \times 10.75 = 245 \#/. \\ w_{0.9D} &= 0.9 \times 6 \times 10.75 = 58 \#/. \end{aligned} \right\} w_{net} = 187 \#/.$$

$$M_u = 0.187 \times 20^2 / 8 = 9.35 \text{ k}' = 112 \text{ k}''$$

$$V_u = 0.187 \times 10 = 1.87 \text{ k.}$$

Stress Check U (SEE CFS OUTPUT)
 $U = 2.3 > 1.0$, N.G. REINFORCING REQ'D
 BRACE BOTTOM FLANGE @ MID SPAN.

CONNECTION: (2) 1/2" ϕ Bolts
 w/ 6" x 3/16" Conn. Pl. WELDED TO PIPE COLUMN.
 1/8" FILLET 2 SIDES

BOLTS: $\phi V_n = (2) 13.5 \text{ ksi} \times 0.2 \text{ in}^2 = 5.3 \text{ k} > 1.87 \text{ k}$, OK

CONN. PL = $\phi V_n = 0.9 \times 0.6 \times 36 \times 6 \times 3/16 = 21.9 \text{ k} > 1.87 \text{ k}$, OK

WELD: $\phi V_n = 1.392 \times 6 \times 2 \times 2 \text{ sides} = 33.4 \text{ k} > 1.87 \text{ k}$, OK



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CHECK (E) "2" BEAM FOR WIND UPLIFT (CASE 2 w/STORAGE)

GouN LC: 0.9D + WL

$$L = 20'$$

$$W = 245 \#/ft \uparrow$$

$$0.9 W_{DL} = 58 \#/ft \downarrow$$

$$0.9 W_{STORAGE} = 0.9(20 \text{ pcft} \times 2.5 \times 2.67 + 10 \#/ft) = 130 \#/ft$$

$$W_{net} = 57 \#/ft \uparrow$$

$$M_u = -2850 \# \cdot ft = -34.2 \# \cdot k$$

$$V_u = 570 \# = 0.57 \# \cdot k$$

STRESS CHECK $U = 0.577 < 1.0, \text{OK}$
 \uparrow SEE CFS OUTPUT.

NO REINFORCING REQD

CONN: (2) 1/2" ϕ M.B.

$$V_u = 0.57 \# \cdot k < 5.3 \# \cdot k, \text{CONN BOLTS } \underline{\text{OK}}$$

$$< 21.9 \# \cdot k, \text{SHEAR CONN. } \underline{\text{OK}}$$

$$< 33.4 \# \cdot k, \text{WELD CONN. } \underline{\text{OK}}$$

CHECK (E) Z" BEAM FOR GRAVITY (CASE 3 w/o STORAGE)

$$\text{GOVN L.C.} = 1.2D + 1.6L$$

$$w_u = 20 \times 9.75 = 195 \text{ \#/'}$$

$$w_{DL} = 6 \times 9.75 = 59 \text{ \#/'}$$

$$w_u = 382 \text{ \#/'}$$

$$M_u = 19.1 \text{ K'} = 229 \text{ K''}$$

$$V_u = 3.8 \text{ K}$$

$$\text{STRESS CHECK } U = 0.985 < 1.0, \underline{\text{OK}}$$

NO REINFORCING REQ'D

CONN. : (2) 1/2" ϕ M.B.

$$V_u = 4.2 \text{ K} < 5.3 \text{ K}, \text{ CONN. BOLTS } \underline{\text{OK}}$$

$$< 21.9 \text{ K}, \text{ SHEAR CONN. } \underline{\text{OK}}$$

$$< 33.4 \text{ K}, \text{ WELD CONN. } \underline{\text{OK}}$$



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CHECK (E) "Z" BEAM FOR GRAVITY (CASE 4 W/ STORAGE)

LC: 1.2D+1.6L

$$\left. \begin{aligned} w_{LL} &= 195 \text{ #/ft} (3/4) = 146 \text{ #/ft} \\ w_{DL} &= 59 \text{ #/ft} (3/4) = 44 \text{ #/ft} \\ w_{STORAGE} &= 144 \text{ #/ft} / 2 = 72 \text{ #/ft} \end{aligned} \right\} w_u = 313 \text{ #/ft}$$

$M_u = 18.7 \text{ K'} = 224 \text{ K''} < M_u = 309 \text{ K''}$ OK

$V_u = 3.7 \text{ K} < \phi V_n = 24.9 \text{ K}$ OK

COMBINED STRESS U

$U = 0.725 < 1.0$ OK

CONN: (2) 1/2" ϕ MB

REINFORCING NOT REQ'D

$V_u = 4.0 \text{ K} < 5.3 \text{ K}$ BOLTS CONN. OK

$< 21.9 \text{ K}$ SHEAR PL CONN. OK

$< 33.4 \text{ K}$ WELD CONN. OK



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CFS Version 9.0.4
 Section: LagunaWoods.cfss
 Zee 10x3.5x1-12 Gage

Rev. Date: 5/18/2016

CASE 1

Printed: 5/18/2016 Z purlin check with wind uplift load w/o storage load

Full Section Properties

Area	1.8554 in ²	Wt.	0.0063084 k/ft	Width	18.244 in
Ix	28.152 in ⁴	rx	3.8952 in	Ixy	8.448 in ⁴
Sx(t)	5.6304 in ³	y(t)	5.0000 in	α	-17.876 deg
Sx(b)	5.6304 in ³	y(b)	5.0000 in		
		Height	10.0000 in		
Iy	4.684 in ⁴	ry	1.5888 in	Xo	0.0000 in
Sy(l)	1.3579 in ³	x(l)	3.4492 in	Yo	0.0000 in
Sy(r)	1.3579 in ³	x(r)	3.4492 in	jx	0.0000 in
		Width	6.8983 in	jy	0.0000 in
I1	30.877 in ⁴	r1	4.0794 in		
I2	1.959 in ⁴	r2	1.0274 in		
Ic	32.836 in ⁴	rc	4.2068 in	Cw	81.230 in ⁶
Io	32.836 in ⁴	ro	4.2068 in	J	0.006397 in ⁴

Member Check - 1999 AISI Specification (LRFD)

Material Type: A572 Grade 50, Fy=50 ksi

Design Parameters:

Lx	20.000 ft	Ly	20.000 ft	Lt	20.000 ft
Kx	1.0000	Ky	1.0000	Kt	1.0000
Cbx	1.0000	Cby	1.0000	ex	0.0000 in
Cmx	1.0000	Cmy	1.0000	ey	0.0000 in

Braced Flange: Top kφ 0 k
 Red. Factor, R: 0 Lm 20.000 ft

Loads:	P	Mx	Vy	My	Vx
	(k)	(k-in)	(k)	(k-in)	(k)
Entered	0.000	-112.00	1.900	0.00	0.000
Applied	0.000	-112.00	1.900	0.00	0.000
Strength	23.589	48.11	14.201	49.44	18.255

Effective section properties at applied loads:

Ae	1.8554 in ²	Ixe	28.152 in ⁴	Iye	4.684 in ⁴
		Sxe(t)	5.6304 in ³	Sye(l)	1.3579 in ³
		Sxe(b)	5.6304 in ³	Sye(r)	1.3579 in ³

Interaction Equations

AISI Eq. C5.2.2-1 (P, Mx, My)	0.000 + 2.328 + 0.000 = 2.328 > 1.0
AISI Eq. C5.2.2-2 (P, Mx, My)	0.000 + 2.328 + 0.000 = 2.328 > 1.0
AISI Eq. C3.3.2-1 (Mx, Vy)	0.218 + 0.018 = 0.236 < 1.0
AISI Eq. C3.3.2-1 (My, Vx)	0.000 + 0.000 = 0.000 < 1.0

OVERSTRESSED,
 PURLIN NEEDS TO
 BE STRENGTHENED



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CFS Version 9.0.4
 Section: LagunaWoods.cfss
 Zee 10x3.5x1-12 Gage

Rev. Date: 5/18/2016

CASE 2

Printed: 5/18/2016 Z purlin check with wind uplift load w/ storage load

Full Section Properties

Area	2.2451 in ²	Wt.	0.0076334 k/ft	Width	18.077 in
Ix	33.780 in ⁴	rx	3.8789 in	Ixy	10.060 in ⁴
Sx(t)	6.7560 in ³	y(t)	5.0000 in	α	-17.732 deg
Sx(b)	6.7560 in ³	y(b)	5.0000 in		
		Height	10.0000 in		
Iy	5.535 in ⁴	ry	1.5702 in	Xo	0.0000 in
Sy(l)	1.6101 in ³	x(l)	3.4379 in	Yo	0.0000 in
Sy(r)	1.6101 in ³	x(r)	3.4379 in	jx	0.0000 in
		Width	6.8758 in	jy	0.0000 in
I1	36.996 in ⁴	r1	4.0594 in		
I2	2.319 in ⁴	r2	1.0163 in		
Ic	39.315 in ⁴	rc	4.1847 in	Cw	95.608 in ⁶
Io	39.315 in ⁴	ro	4.1847 in	J	0.011544 in ⁴

Member Check - 1999 AISI Specification (LRFD)

Material Type: A572 Grade 50, Fy=50 ksi

Design Parameters:

Lx	20.000 ft	Ly	20.000 ft	Lt	20.000 ft
Kx	1.0000	Ky	1.0000	Kt	1.0000
Cbx	1.0000	Cby	1.0000	ex	0.0000 in
Cmx	1.0000	Cmy	1.0000	ey	0.0000 in
Braced Flange: Top		kφ	0 k		
Red. Factor, R: 0		Lm	20.000 ft		

Loads:	P (k)	Mx (k-in)	Vy (k)	My (k-in)	Vx (k)
Entered	0.000	-34.000	0.570	0.000	0.000
Applied	0.000	-34.000	0.570	0.000	0.000
Strength	29.260	58.969	24.936	65.154	21.454

Effective section properties at applied loads:

Ae	2.2451 in ²	Ixe	33.780 in ⁴	Iye	5.535 in ⁴
		Sxe(t)	6.7560 in ³	Sye(l)	1.6101 in ³
		Sxe(b)	6.7560 in ³	Sye(r)	1.6101 in ³

Interaction Equations

AISI Eq. C5.2.2-1 (P, Mx, My)	0.000 + 0.577 + 0.000	= 0.577	<= 1.0
AISI Eq. C5.2.2-2 (P, Mx, My)	0.000 + 0.577 + 0.000	= 0.577	<= 1.0
AISI Eq. C3.3.2-1 (Mx, Vy)	0.012 + 0.001	= 0.013	<= 1.0
AISI Eq. C3.3.2-1 (My, Vx)	0.000 + 0.000	= 0.000	<= 1.0

OK



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CFS Version 9.0.4
 Section: LagunaWoods.cfss
 Zee 10x3.5x1-12 Gage

Rev. Date: 5/19/2016

CASE 3

Printed: 5/19/2016

Z purlin check with gravity load w/o storage load

Full Section Properties

Area	1.8554 in ²	Wt.	0.0063084 k/ft	Width	18.244 in
Ix	28.152 in ⁴	rx	3.8952 in	Ixy	8.448 in ⁴
Sx(t)	5.6304 in ³	y(t)	5.0000 in	α	-17.876 deg
Sx(b)	5.6304 in ³	y(b)	5.0000 in		
		Height	10.0000 in		
Iy	4.684 in ⁴	ry	1.5888 in	Xo	0.0000 in
Sy(l)	1.3579 in ³	x(l)	3.4492 in	Yo	0.0000 in
Sy(r)	1.3579 in ³	x(r)	3.4492 in	jx	0.0000 in
		Width	6.8983 in	jy	0.0000 in
I1	30.877 in ⁴	r1	4.0794 in		
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Ic	32.836 in ⁴	rc	4.2068 in	Cw	81.230 in ⁶
Io	32.836 in ⁴	ro	4.2068 in	J	0.006397 in ⁴

Member Check - 1999 AISI Specification (LRFD)

Material Type: A572 Grade 50, Fy=50 ksi

Design Parameters:

Lx	19.500 ft	Ly	19.500 ft	Lt	19.500 ft
Kx	1.0000	Ky	1.0000	Kt	1.0000
Cbx	1.0000	Cby	1.0000	ex	0.0000 in
Cmx	1.0000	Cmy	1.0000	ey	0.0000 in

Braced Flange: Top kφ 0 k
 Red. Factor, R: 0 Lm 19.500 ft

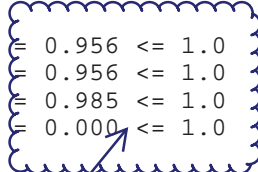
Loads:	P (k)	Mx (k-in)	Vy (k)	My (k-in)	Vx (k)
Entered	0.000	229.00	3.800	0.00	0.000
Applied	0.000	229.00	3.800	0.00	0.000
Strength	23.589	239.62	14.201	49.57	18.255

Effective section properties at applied loads:

Ae	1.8080 in ²	Ixe	27.226 in ⁴	Iye	4.182 in ⁴
		Sxe(t)	5.3237 in ³	Sye(l)	1.2426 in ³
		Sxe(b)	5.5724 in ³	Sye(r)	1.1838 in ³

Interaction Equations

AISI Eq. C5.2.2-1 (P, Mx, My)	0.000 + 0.956 + 0.000	= 0.956	<= 1.0
AISI Eq. C5.2.2-2 (P, Mx, My)	0.000 + 0.956 + 0.000	= 0.956	<= 1.0
AISI Eq. C3.3.2-1 (Mx, Vy)	0.913 + 0.072	= 0.985	<= 1.0
AISI Eq. C3.3.2-1 (My, Vx)	0.000 + 0.000	= 0.000	<= 1.0



OK



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Rev. Date: 5/19/2016

CASE 4

Printed: 5/19/2016

Z purlin check with gravity load w/ storage load

Full Section Properties

Area	2.2451 in ²	Wt.	0.0076334 k/ft	Width	18.077 in
Ix	33.780 in ⁴	rx	3.8789 in	Ixy	10.060 in ⁴
Sx(t)	6.7560 in ³	y(t)	5.0000 in	α	-17.732 deg
Sx(b)	6.7560 in ³	y(b)	5.0000 in		
		Height	10.0000 in		
Iy	5.535 in ⁴	ry	1.5702 in	Xo	0.0000 in
Sy(l)	1.6101 in ³	x(l)	3.4379 in	Yo	0.0000 in
Sy(r)	1.6101 in ³	x(r)	3.4379 in	jx	0.0000 in
		Width	6.8758 in	jy	0.0000 in
I1	36.996 in ⁴	r1	4.0594 in		
I2	2.319 in ⁴	r2	1.0163 in		
Ic	39.315 in ⁴	rc	4.1847 in	Cw	95.608 in ⁶
Io	39.315 in ⁴	ro	4.1847 in	J	0.011544 in ⁴

Member Check - 1999 AISI Specification (LRFD)

Material Type: A572 Grade 50, Fy=50 ksi

Design Parameters:

Lx	19.500 ft	Ly	19.500 ft	Lt	19.500 ft
Kx	1.0000	Ky	1.0000	Kt	1.0000
Cbx	1.0000	Cby	1.0000	ex	0.0000 in
Cmx	1.0000	Cmy	1.0000	ey	0.0000 in
Braced Flange: Top		kφ	0 k		
Red. Factor, R:	0	Lm	19.500 ft		

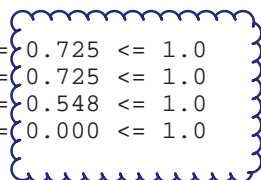
Loads:	P	Mx	Vy	My	Vx
	(k)	(k-in)	(k)	(k-in)	(k)
Entered	0.000	224.00	3.700	0.00	0.000
Applied	0.000	224.00	3.700	0.00	0.000
Strength	29.260	308.86	24.936	65.40	21.454

Effective section properties at applied loads:

Ae	2.2451 in ²	Ixe	33.780 in ⁴	Iye	5.535 in ⁴
		Sxe(t)	6.7560 in ³	Sye(l)	1.6101 in ³
		Sxe(b)	6.7560 in ³	Sye(r)	1.6101 in ³

Interaction Equations

AISI Eq. C5.2.2-1 (P, Mx, My)	0.000 + 0.725 + 0.000 = 0.725 <= 1.0
AISI Eq. C5.2.2-2 (P, Mx, My)	0.000 + 0.725 + 0.000 = 0.725 <= 1.0
AISI Eq. C3.3.2-1 (Mx, Vy)	0.526 + 0.022 = 0.548 <= 1.0
AISI Eq. C3.3.2-1 (My, Vx)	0.000 + 0.000 = 0.000 <= 1.0



OK