Structural Calculations

For

HELIODYNE SOLAR COLLECTOR RACK STRUCTURES

Gobi 410 at 45 degrees

FOR HELIODYNE, INC.

EV Engineering, LLC
projects@evengineersnet.com
http://www.evengineersnet.com

Table of Content

Scope of Work

This report is for the Heliodyne Rack Stucture with Gobi 410 Collector at 45 degrees. The purpose of the analysis was to determine appropriate loadings for the Heliodyne rack structure with Gobi 410 collectors at 45 degrees following the currentmost design codes with an emphasis on California. The analysis looked at Dead loads from collectors and racking, wind loads scenarios, as well as light snow loads. Both wind exposure B and C which are frequently encountered in Califonia were considered.

Conclusion

After analysis, the rack has been determined to be adequate to support imposed loads in conditions outlined below. With the exception of special wind region and High snow areas, most low altitude California areas should be covered by the tabluated conditions. All Racking and collector parts shall be designed and installed per manufacturer's approved installation specifications.

Table 1. Design Criteria

Codes	2019 California Building Code (ASCE 7-16) & 2016 California Building Code (ASCE 7-10)
Risk Category	II

Condition 1.

Wind Load	(Monoslope Open Structure)	
	V	110 mph
	Exposure	C (20 feet max height)
Dead Load	D	3.3 psf
Ground Snow	S	0 psf
Seismic	S_S	2.2
	S_{DS}	1.5

Condition 2.

Wind Load	(Monoslope Open Structure)	
	V	110 mph
	Exposure	B
Dead Load	D	3.3 psf
Ground Snow	S	30 psf
Seismic	S_S	2.2
	S_{DS}	1.5

References

ASCE Minimum Design Loads for Buildings and Other Structures (ASCE7-16 and ASCE 7-10)
2015 National Design Specification for Wood Construction (NDS)
2010 Aluminum Design Manual (ADM)

Notes and Limits of Scope of Work

1. Racks are Installed on both long sides of the collectors with a maximum spacing of 4'
2. The strength of the collectors is not part of the scope of this report.
3. Engineer of Record for each specific site shall be responsible for its analysis and design forces
4. This report can be used for reference only for sites meeting conditon 1 or 2
5. For conditon 1, maximum building height considered is 20 feet
6. Engineer of Record for each specific installation shall be responsible for the design of fasteners
7. Atmospheric Ice loading and flood loading are beyond the scope of this report.
8. The rack structure in this report is defined in a drawing package prepared by Heliodyne, Inc.
   Titled Heliodyne Rack Installation Guide, dated 12/15/2010.

Wind Load Back Ground

Background

After several iteration, it was evident that the mounitng clip would govern the desing. In the Heliodyne report by MATRIX Consulting Engineers, a Finite Element Analysis was performed and resulted in clip capacity at different angles. In light of this informaton, We analysed different wind speeds in combination with varying exposure categories and settled on speeds that would not result in forces greater than what the clip can handle. All the iteration focused on California

In light of new research and studies, ASCE 7-16 was introduced with mostly reduced basic wind speed maps. With the exception of special wind region, all category II structures in California have basic wind speeds of 100 mph or less. Our analysis tailored for California was run using 110 mph in order to enveloppe wind speed in ASCE 7-16 as well as ASCE 7-10.

Velocity Pressure was calculated as follow:

$q_h = 0.00256KzK_{zt}K_dV^2$ eq. 26.10-1 ASCE 7-10

$q_h = 0.00256KzK_{zt}K_dK_eV^2$ eq. 26.10-1 ASCE 7-16

Site specific variables are:

Basic wind speed: V

Velocity pressure exposure coefficient, evaluated at height z: Kz

Topographic factor: Kzt

Ground elevation Factor Ke (Conservatively used 1)

The newly added ground elevation factor reduces with altitude, we opted to conservatively use 1 given many different altitude possibilities.

Non Site specific variables are:

Wind directionality factor: Kd = 0.85

Gust effect factor: G = 0.85

The Net design pressure was calculated as follow:

$p=q_hGC_N$ eq. 27.3-2 ASCE 7-16

C_N= Net pressure Coefficient determined from fig 27.3-4 of ASCE 7-16

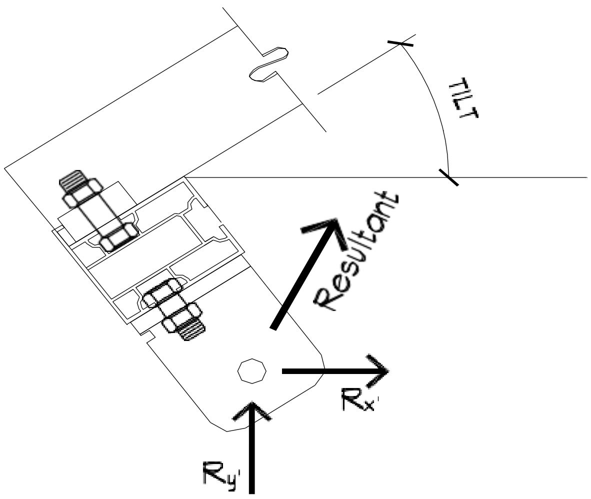
Load Combinations

Stength Level Combination (LRFD) per ASCE 7-16 Sections 2.3.1

LC1=	LC1= 1.2D+1.0WA
LC2=	LC2= 1.2D+1.0WB
LC3=	LC3= 1.2D+1.0WC
LC4=	LC4= 1.2D+1.0WD
LC5=	LC5= 0.9D+1.0WA
LC6=	LC6= 0.9D+1.0WB
LC7=	LC7= 0.9D+1.0WC
LC8=	LC8= 0.9D+1.0WD

Clip, Rail, and Foot Capacity Summary

Capacity below are extracted from the Heliodyne Rack Structure w/Gobi 410 Collector @ 45 degrees Report by MATRIX Consulting Engineers.



Tilt (Degrees)	Load Direction	Ry	Rx	Ry
35	Tension	-630	-361	-516
35	Comp.	1274	731	1044
45	Tension	-571	-404	-404
45	Comp.	721	510	510

Job Information

	Engineer	Checked	Approved
Name:	EM		
Date:	26-Dec-19		

Structure Type	SPACE FRAME

Number of Nodes	6	Highest Node	6
Number of Elements	5	Highest Beam	5

Number of Basic Load Cases	-2
Number of Combination Load Cases	27

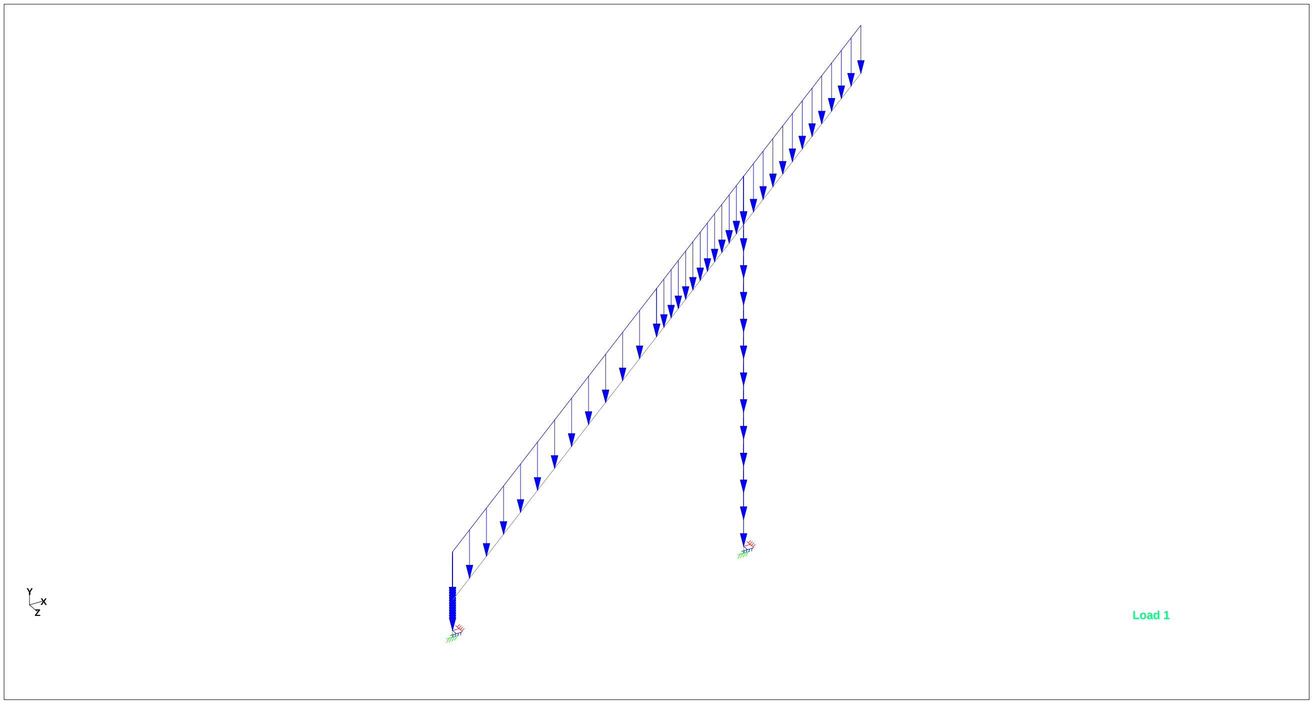
Included in this printout are data for:

All	The Whole Structure

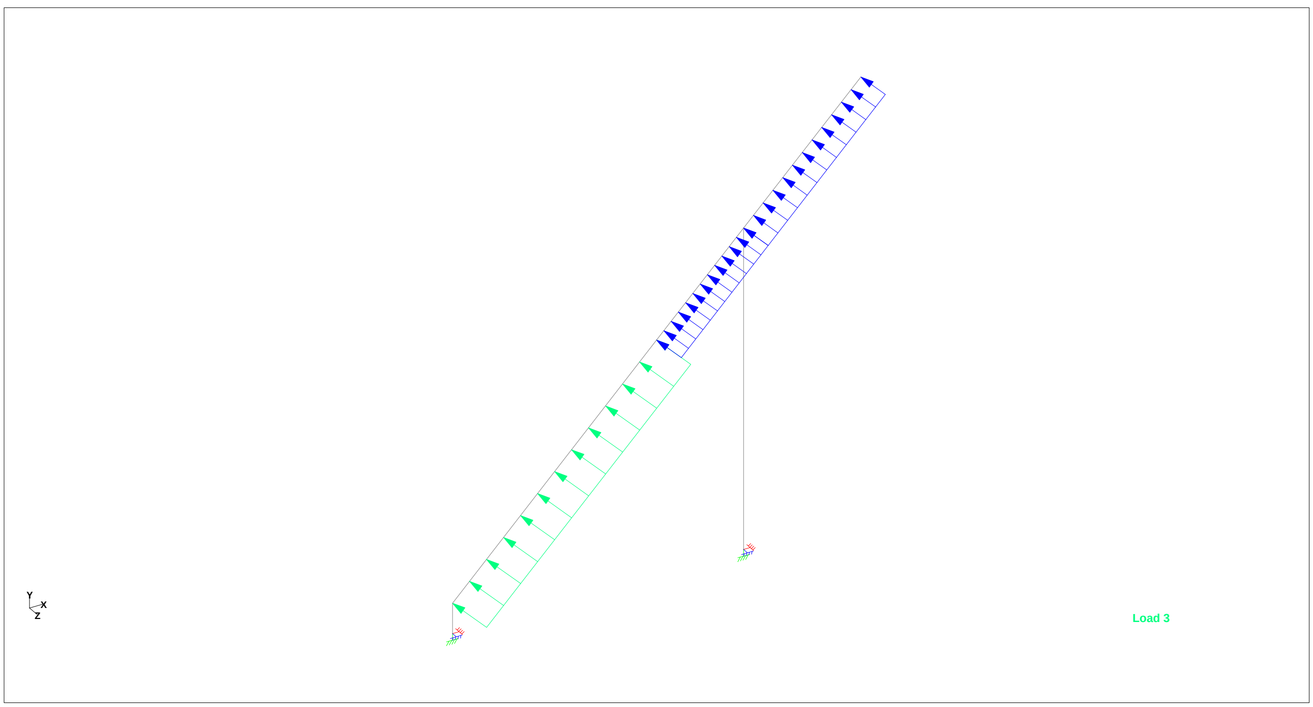
Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	DL1 - DEAD LOAD 1
Primary	2	SL1 - SNOW LOAD 1
Primary	3	WLA
Primary	4	WLB
Primary	5	WLC
Primary	6	WLD
Combination	9	1.2DL1+1.6SL1+0.5WLB
Combination	10	LRFD REACTION COMBOS
Combination	11	1.2DL1+1.6SL1+0.5WLA
Combination	12	1.2DL1+1.6SL1+0.5WLC
Combination	13	1.2DL1+1.6SL1+0.5WLD
Combination	14	1.2DL1+1.0WLA+.5SL1
Combination	15	1.2DL1+1.0WLB+.5SL1
Combination	16	1.2DL1+1.0WLC+.5SL1
Combination	17	1.2DL1+1.0WLD+.5SL1
Combination	18	0.9DL1+1.0WLA
Combination	19	0.9DL2+1.0WLB
Combination	20	0.9DL2+1.0WLC
Combination	21	0.9DL2+1.0WLD

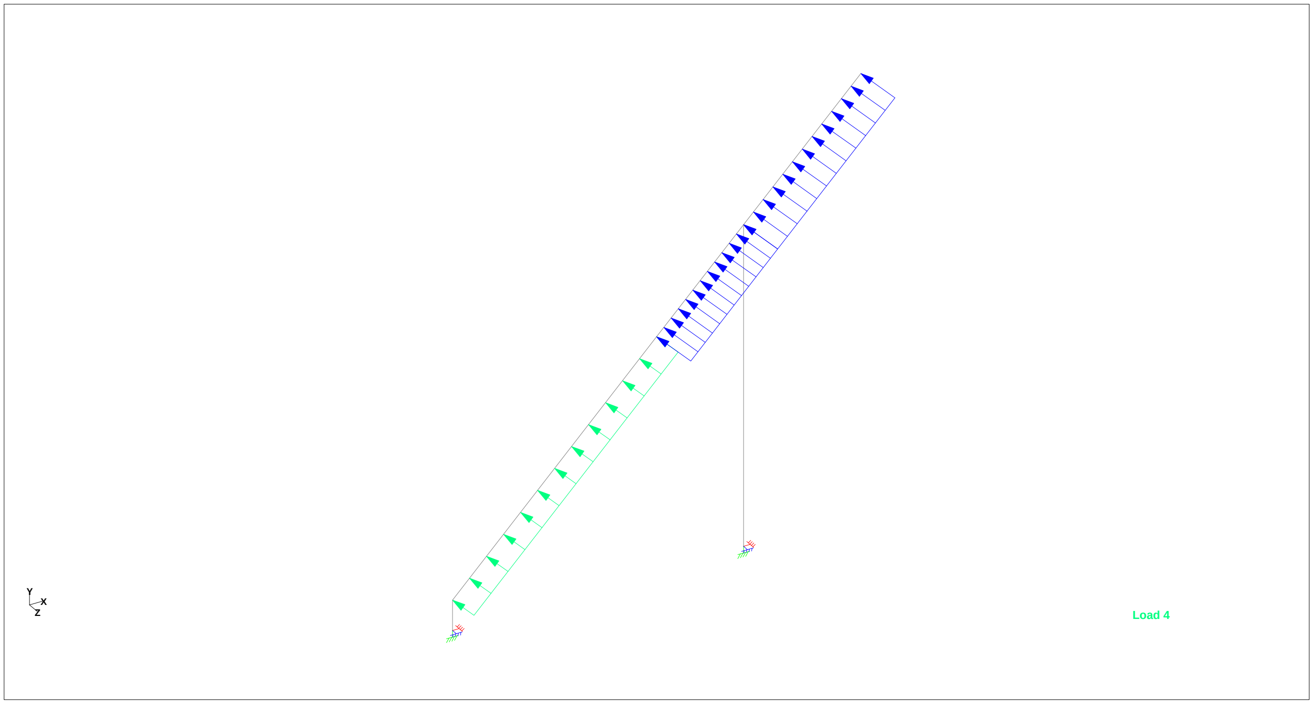
EV ENGINEERING	
Job Title Gobi	
Client Heliodyne	



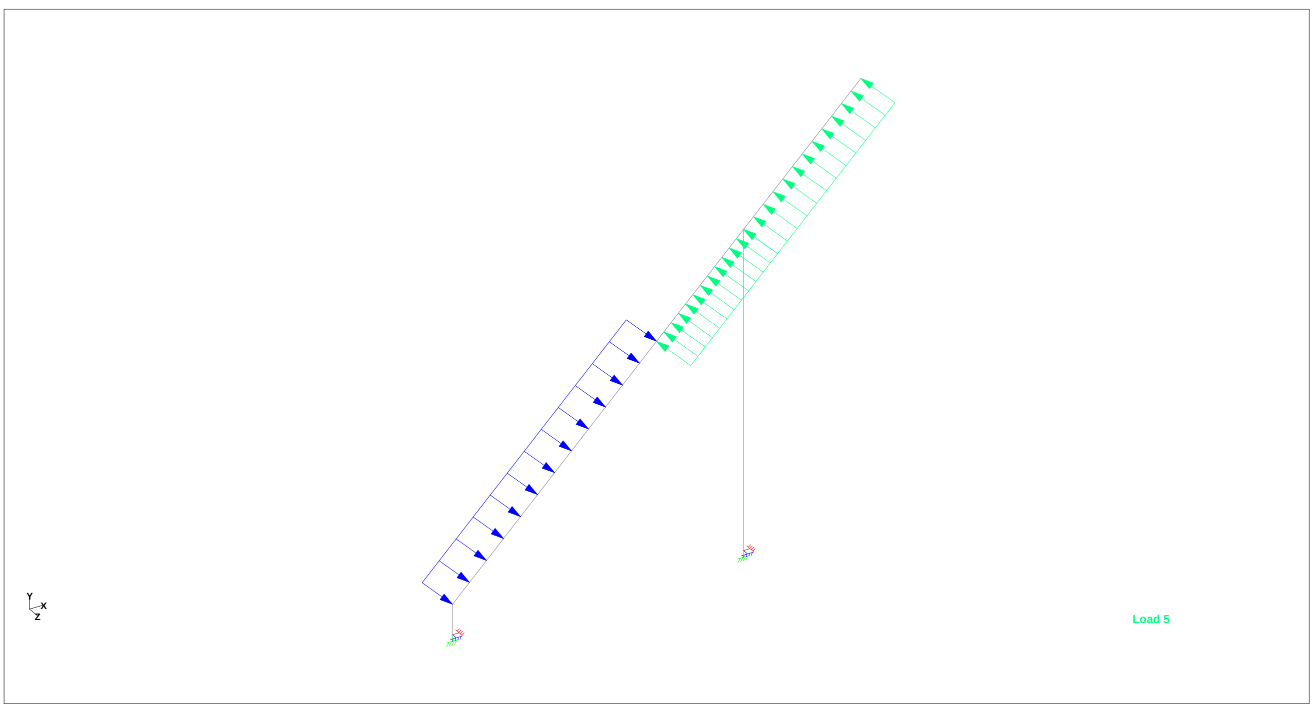
Dead Load



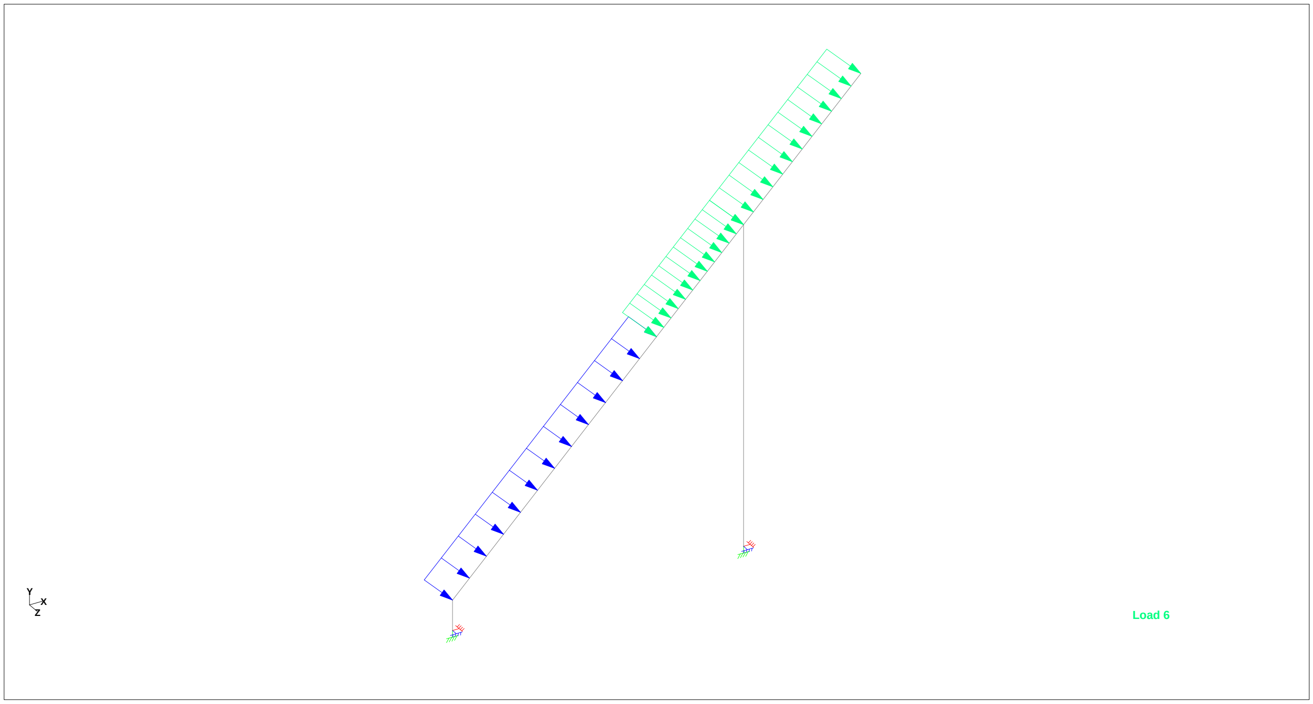
Wind_A



Wind_B

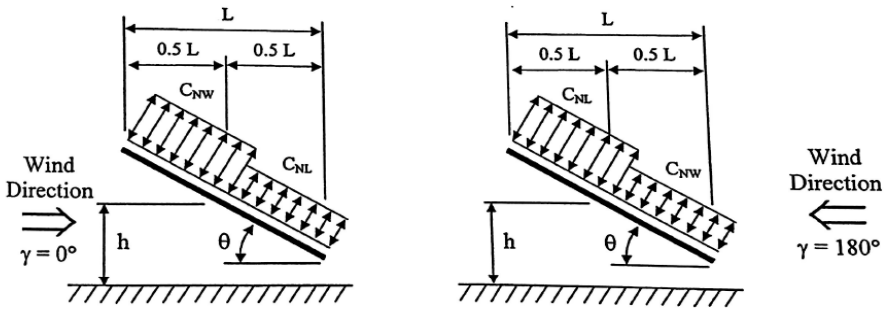


Wind_C



Wind_D

Wind Load (Exposure C)



Wind Load Calculation: $q = 0.00256K_zK_eK_dK_{zt}V^2I_w$

Wind Speed:	110 mph	**Exposure:**	C
K_e =	1.00	K_z =	0.9
K_{zt} =	1.00	I_w =	1.0
K_d =	0.85	Mean Roof Height (h) =	20.0 ft
q =	**23.7 psf**		

Trib Width 4 ft

Roof Pressure Coefficients (ASCE 7-16/ASCE 7-10):

Cos (Θ) = 0.707

Tilt (Θ) = 45.0 deg

Sin (Θ) = 0.707

Leg Horiz. Trib. 5.064 ft

	Wind Direction, γ = 0 deg		0.0 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-1.3	-1.8	0.8	-0.9
B	-1.9	-1.2	2.1	0.4

Roof Pressures ($p = qGC_N$ (psf)): G = 0.85

	Wind Direction, γ = 0 deg		Wind Direction, γ = 180 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-26.2	-36.3	16.1	-18.1
B	-38.3	-24.2	42.3	8.1

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-375	-375	-519	-519	231	231	-260	-260
B	-548	-548	-346	-346	606	606	115	115

Dead Load	3.3 psf		
1.2D	3.96 psf	0.9D	2.97 psf
Linear	15.84 plf		11.88 plf
Per Post	80.15 lbs		60.1 lbs

Down Force 1.2D+1.0W

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-375	-295	-519	-439	231	311	-260	-179
B	-548	-468	-346	-266	606	686	115	196

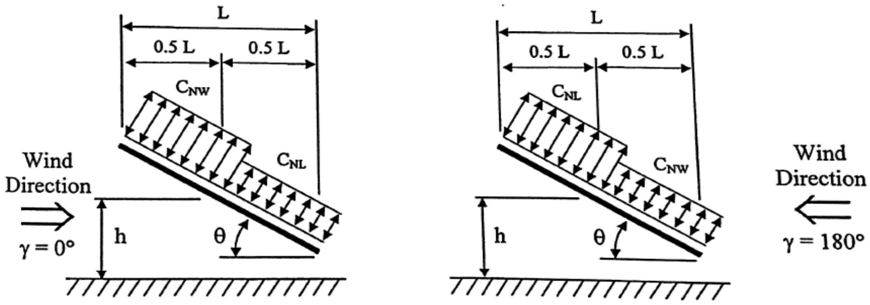
(lbs)	Loads	Capacity	Ratio	Result
Vertical +	686	721	0.95	**OK**
Vertical -	-468	571	0.82	**OK**
Lateral +	606	640	0.95	**OK**
Lateral -	-548	683	0.80	**OK**

Uplift 0.9D+W

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-375	-315	-519	-459	231	291	-260	-200
B	-548	-488	-346	-286	606	666	115	176

(lbs)	Loads	Capacity	Ratio	Result
Vertical +	666	721	0.92	**OK**
Vertical -	-488	571	0.85	**OK**
Lateral +	606	640	0.95	**OK**
Lateral -	-548	683	0.80	**OK**

Wind Load (Exposure B)



Wind Load Calculation: $q = 0.00256K_zK_eK_dK_{zt}V^2I_w$

Wind Speed: 110 mph **Exposure:** B

K_e =	1.00	K_z =	0.7
K_{zt} =	1.00	I_w =	1.0
K_d =	0.85	Mean Roof Height (h) =	33.0 ft
q =	**18.5 psf**		

Trib Width 4 ft

Roof Pressure Coefficients (ASCE 7-16/ASCE 7-10): Cos (Θ) = 0.707

Tilt (Θ) = 45.0 deg Sin (Θ) = 0.707

Leg Horiz. Trib. 5.064 ft

	Wind Direction, γ = 0 deg		0.0 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-1.3	-1.8	0.8	-0.9
B	-1.9	-1.2	2.1	0.4

Roof Pressures ($p = qGC_N$ (psf)): G = 0.85

	Wind Direction, γ = 0 deg		Wind Direction, γ = 180 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-20.4	-28.2	12.6	-14.1
B	-29.8	-18.8	32.9	6.3

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-292	-292	-404	-404	180	180	-202	-202
B	-427	-427	-270	-270	472	472	90	90

Dead Load	3.3 psf			
1.2D	3.96 psf		0.9D	2.97 psf
Linear	15.84 plf			11.88 plf
Per Post	80.15 lbs			60.1 lbs

Down Force 1.2D+1.0W

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-292	-212	-404	-324	180	260	-202	-122
B	-427	-347	-270	-190	472	552	90	170

(lbs)	Loads	Capacity	Ratio	Result
Vertical +	552	721	0.77	**OK**
Vertical -	-347	571	0.61	**OK**
Lateral +	472	640	0.74	**OK**
Lateral -	-427	683	0.63	**OK**

Uplift 0.9D+W

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-292	-232	-404	-344	180	240	-202	-142
B	-427	-367	-270	-210	472	532	90	150

(lbs)	Loads	Capacity	Ratio	Result
Vertical +	532	721	0.74	**OK**
Vertical -	-367	571	0.64	**OK**
Lateral +	472	640	0.74	**OK**
Lateral -	-427	683	0.63	**OK**

Wind (Exposure B) & Snow

Wind Load Calculation: $q = 0.00256K_zK_eK_dK_{zt}V^2I_w$

Vind Speed:	110 mph	**Exposure:**	B
K_e =	1.00	K_z =	0.7
K_{zt} =	1.00	I_w =	1.0
K_d =	0.85	Mean Roof Height (h) =	33.0 ft
q =	**18.5 psf**	Trib Width	4 ft

Roof Pressure Coefficients (ASCE 7-16/ASCE 7-10):

Cos (Θ) = 0.707

Tilt (Θ) = 45.0 deg

Sin (Θ) = 0.707

Leg Horiz. Trib. 5.064 ft

	Wind Direction, γ = 0 deg		0.0 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-1.3	-1.8	0.8	-0.9
B	-1.9	-1.2	2.1	0.4

Roof Pressures ($p = qGC_N$ (psf)): G = 0.85

	Wind Direction, γ = 0 deg		Wind Direction, γ = 180 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-20.4	-28.2	12.6	-14.1
B	-29.8	-18.8	32.9	6.3

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-292	-292	-404	-404	180	180	-202	-202
B	-427	-427	-270	-270	472	472	90	90

Dead Load	3.3 psf
1.2D	3.96 psf
Linear	15.84 plf
Per Post	80.15 lbs

Snow Load Calculation: $p_f = 0.7C_eC_tI_sp_g$

ound Snow:	30.0 psf		
C_e =	0.9		
C_t =	1.2		
I_s =	1.0		
p_f =	**22.7 psf**		
P_s=Cs*p_f =	**9.5 psf**		
Trib.=	**38**	**0.5S**	**1.6S**
Per post=	**193**	96	309

Case 1 **1.2D+1W+0.5S**

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-292	-115	-404	-228	180	356	-202	-26
B	-427	-250	-270	-93	472	649	90	267

(lbs)	Loads	Capacity	Ratio	Result
Vertical +	649	721	0.90	**OK**
Vertical -	-250	571	0.44	**OK**
Lateral +	472	640	0.74	**OK**
Lateral -	-427	683	0.63	**OK**

Case 2 **1.2D+0.5W+1.6S**

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-146	243	-202	187	90	479	-101	288
B	-213	175	-135	254	236	625	45	434

(lbs)	Loads	Capacity	Ratio	Result
Vertical +	625	721	0.87	**OK**
Vertical -	175	571	0.31	**OK**
Lateral +	236	640	0.37	**OK**
Lateral -	-213	683	0.31	**OK**

Seismic Loads:

Importance Factor (I) :	I	
Site Class :	D	Assumed
Ss (0.2 sec) =	220 %g	
S1 (1.0 sec) =	93 %g	
S_{DS}=	1.5	
Number of Stories:	1	
Building System:	**Component and Cladding**	

Tributary Area=	40.5	ft^2
Amplification factor, ap =	1	
Spectral Acceleration, SDS =	1.5	
Operating Weight, Wp (psf) =	3.3	
Response Modification Factor, Rp =	1.5	
Importance Factor, Ip =	1	
Reduction Factor, ρ=	1	
Height above ground level, z (ft) =	33	
Mean height, h (ft) =	33	

$$F_p = \frac{0.4\ a_p\ S_{DS} W_p * (1+2*z/h)}{(R_p/I_p)} = 1.173\ W_p$$

Fp Min. 0.3 S_{DS} Ip Wp=	0.44	Wp
Fp Max. 1.6 S_{DS} Ip Wp=	2.35	Wp

Forces in X-direction

Eh=ρ Fp Wp Lp=	156.9	<	472	lbs
		Wind Governs		

Forces in Y-direction

Ev=0.2 S_{DS} Wp Lp=	39.2	<	427	lbs
		Wind Governs		

Anchor Design

Wind Load Calculation: $q = 0.00256K_zK_eK_dK_{zt}V^2I_w$

Wind Speed:	110 mph	**Exposure:**	C
K_e =	1.00	K_z =	0.9
K_{zt} =	1.00	I_w =	1.0
K_d =	0.85	Mean Roof Height (h) =	20.0 ft
q =	**23.7 psf**		

Trib Width 4 ft

Roof Pressure Coefficients (ASCE 7-16/ASCE 7-10):

Cos (Θ) = 0.707

Tilt (Θ) = 45.0 deg

Sin (Θ) = 0.707

Leg Horiz. Trib. 5.064 ft

	Wind Direction, γ = 0 deg		0.0 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-1.3	-1.8	0.8	-0.9
B	-1.9	-1.2	2.1	0.4

Roof Pressures ($p = qGC_N$ (psf)): G = 0.85

	Wind Direction, γ = 0 deg		Wind Direction, γ = 180 deg	
	Obstructed Wind Flow		Obstructed Wind Flow	
Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-26.2	-36.3	16.1	-18.1
B	-38.3	-24.2	42.3	8.1

	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-375	-375	-519	-519	231	231	-260	-260
B	-548	-548	-346	-346	606	606	115	115

Snow Load Calculation: $p_f = 0.7C_eC_tI_sp_g$

Ground Snow:	30.0 psf		**Dead Load**	3.3 psf
C_e =	0.9		D	3.3 psf
C_t =	1.2		Linear	13.2 plf
I_s =	1.0		Per Post	66.79 lbs
p_f =	**22.7 psf**			
$P_s = Cs*p_f$ =	**9.5 psf**			
Trib.=	**38**	**0.75S**	0.6D	40.08 lbs
Per post=	**193**	145		

Case 1	D+0.75(0.6W)+0.75S							
	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-169	43	-234	-22	104	315	-117	95
B	-247	-35	-156	56	273	484	52	263

Case 2	D+0.6W							
	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-225	-158	-312	-245	138	205	-156	-89
B	-329	-262	-208	-141	364	430	69	136

Case 3	0.6D+0.6W							
	Wind Direction, γ = 0 deg				Wind Direction, γ = 180 deg			
	Rear		**Front**		**Front**		**Rear**	
	C_{NW}		C_{NL}		C_{NW}		C_{NL}	
	X	Y	X	Y	X	Y	X	Y
A	-225	-185	-312	-272	138	179	-156	-116
B	-329	-289	-208	-168	364	404	69	109

Lag Screw Connection

Attachement max. spacing=	4	ft		
3/8" Lag Screw Withdrawl Value=	305	lb/in	Table 12.2A - NDS	
Lag Screw Penetration=	3	in	No. 2 DFL assumed	
Prying Coefficient	1.4			
Allowable Capacity with CD=	1045.7	lbs		

Net Uplift	289	lbs			
Max shear	364	lbs	<	576 lbs	**Ok**
Max Moment	**2075**	**ft-in**			
Tension/Compression	691.6	lbs			
Total Uplift (envelope)	692	lbs	<	1046 lbs	**Ok**

Pv seismic dead weight is negligible to result in significant seismic uplift, therefore the wind uplift

Embedment is measured from the top of the framing member to the tapered tip of a lag screw. Embedment in sheading or other material does not count.

In this design, 3/8" diameter lag bolts with a minimum 3" effective embedment as defined above into a DFL #2 or better is sufficient provided NDS 2015 design requirements are followed.

Design of the framing supporting Gobi 410 is not part of our scope and should be verified and confirmed by the SEOR.