Design Calculations

For

Knotwood Pergola Batten Calculations

Date Prepared … June 16, 2021

Prepared for:

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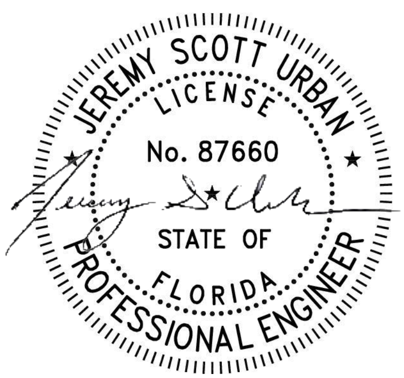

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DESIGN CODES AND STANDARDS

The following codes and standards, including all specifications referenced within, apply to the design and construction of this project:

- IBC, INTERNATIONAL BUILDING CODE – 2018
- ASCE 7-16, MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES
- ADM, ALUMINUM DESIGN MANUAL – 2015

GENERAL NOTES

1. Contractor to verify all dimensions in the field prior to installation. Do not scale off drawings.
2. All members shall be saw cut in field as required.
3. No splices shall be permitted unless indicated otherwise on the drawings.
4. Touch up all scratches with dealer provided colors to match.
5. Welding is not permitted, unless otherwise indicated on the drawings.
6. The contents show the application of aluminum Equinox framing components only. The installing contractor is to refer to the project documents for additional requirements.
7. Dimensions herein are for engineering purposes only and must be reviewed for the purpose of approval. All conditions are subject to approval and to field verification prior to fabrication or installation.
8. Before ordering, fabricating or erecting any material, make any necessary surveys and measurements to verify that in place work has been built according to the contract documents and are within acceptable tolerances. This includes the original buildings and all additions thereto. Notify the Architect/Engineer and owner's representatives of any discrepancies prior to construction.
9. Temporary bracing of the system and safety during construction is solely the responsibility of the contractor. Temporary bracing of the system shall remain in place until the system is totally in place. Contractor shall coordinate locations of temporary bracing with other contractors. Refer to drawings for additional criteria.
10. This submittal is subject to the review and approval of the project Architect/Engineer of record prior to installation.

DESIGN LOADS

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JOB TITLE	Generic Pergola Battens		
JOB NO.	202100162	**SHEET NO.**	
CALCULATED BY	DSG	**DATE**	6/16/21
CHECKED BY	JU	**DATE**	6/16/21

Code Search

Code: International Building Code 2018

Occupancy:

Occupancy Group = B Business

Risk Category & Importance Factors:

Risk Category =	II
Wind factor =	1.00
Snow factor =	1.00
Seismic factor =	1.00

Type of Construction:

Fire Rating:

Roof =	0.0 hr
Floor =	0.0 hr

Building Geometry:

Roof angle (θ)	0.00 / 12	0.0 deg
Building length (L)	18.5 ft	
Least width (B)	18.5 ft	
Mean Roof Ht (h)	12.0 ft	
Parapet ht above grd	12.0 ft	
Minimum parapet ht	0.0 ft	

Live Loads:

Roof	0 to 200 sf:	20 psf
	200 to 600 sf:	24 - 0.02Area, but not less than 12 psf
	over 600 sf:	12 psf

Floor:

Typical Floor	20 psf
Partitions	N/A
Partitions	N/A
Partitions	N/A

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Wind Loads : ASCE 7- 16

Ultimate Wind Speed	181 mph
Nominal Wind Speed	140.2 mph
Risk Category	II
Exposure Category	C
Enclosure Classif.	Open Building
Internal pressure	+/-0.00
Directionality (Kd)	0.85
Kh case 1	0.849
Kh case 2	0.849
Type of roof	Monoslope

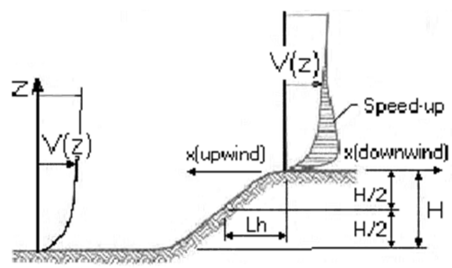
Topographic Factor (Kzt)

Topography	Flat	
Hill Height (H)	0.0 ft	H< 15ft;exp C
Half Hill Length (Lh)	0.0 ft	∴ Kzt=1.0
Actual H/Lh =	0.00	
Use H/Lh =	0.00	
Modified Lh =	0.0 ft	
From top of crest: x =	0.0 ft	
Bldg up/down wind?	downwind	

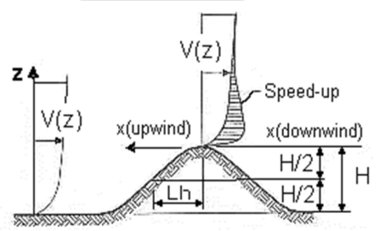
H/Lh= 0.00	K_1 = 0.000
x/Lh = 0.00	K_2 = 0.000
z/Lh = 0.00	K_3 = 1.000

At Mean Roof Ht:

$Kzt = (1+K_1K_2K_3)^2 = 1.00$



ESCARPMENT



2D RIDGE or 3D AXISYMMETRICAL HILL

Gust Effect Factor

h =	12.0 ft
B =	18.5 ft
/z (0.6h) =	15.0 ft

Flexible structure if natural frequency < 1 Hz (T > 1 second).
If building h/B>4 then may be flexible and should be investigated.
h/B = 0.65 Rigid structure (low rise bldg)

G = 0.85 Using rigid structure default

Rigid Structure

ē =	0.20
ℓ =	500 ft
z_{min} =	15 ft
c =	0.20
g_Q, g_v =	3.4
L_z =	427.1 ft
Q =	0.95
I_z =	0.23
G =	0.90 use G = 0.85

Flexible or Dynamically Sensitive Structure

34 ıcy (η_1) =	0.0 Hz				
Damping ratio (β) =	0				
/b =	0.65				
/α =	0.15				
Vz =	152.8				
N_1 =	0.00				
R_n =	0.000				
R_h =	28.282	η =	0.000	h =	12.0 ft
R_B =	28.282	η =	0.000		
R_L =	28.282	η =	0.000		
g_R =	0.000				
R =	0.000				
Gf =	0.000				

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JOB NO. 202100162 **SHEET NO.**
CALCULATED BY DSG **DATE** 6/16/21
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Wind Loads - Open Buildings: 0.25 ≤ h/L ≤ 1.0

Ultimate Wind Pressures

Type of roof = Monoslope Free Roofs
Wind Flow = Clear
G = 0.85
Roof Angle = 0.0 deg

Main Wind Force Resisting System

NOTE: The code requires the MWFRS be designed for a minimum pressure of 16 psf.

Kz = Kh (case 2) = 0.85
Base pressure (qh) = **60.5 psf**

Roof pressures - Wind Normal to Ridge

Wind Flow	Load Case		Wind Direction γ = 0 & 180 deg Cnw	Cnl
Clear Wind Flow	A	Cn =	1.20	0.30
		p =	61.7 psf	15.4 psf
	B	Cn =	-1.10	-0.10
		p =	-56.6 psf	-5.1 psf

NOTE: 1). Cnw and Cnl denote combined pressures from top and bottom roof surfaces.
2). Cnw is pressure on windward half of roof. Cnl is pressure on leeward half of roof.
3). Positive pressures act toward the roof. Negative pressures act away from the roof.

Roof pressures - Wind Parallel to Ridge, γ = 90 deg

Wind Flow	Load Case		Horizontal Distance from Windward Edge ≤ h	>h ≤ 2h	> 2h
Clear Wind Flow	A	Cn =	-0.80	-0.60	-0.30
		p =	-41.2 psf	-30.9 psf	-15.4 psf
	B	Cn =	0.80	0.50	0.30
		p =	41.2 psf	25.7 psf	15.4 psf

h = 12.0 ft
2h = 24.0 ft

Fascia Panels -Horizontal pressures

qp = 60.5 psf
Windward fascia: 90.8 psf (GCpn = +1.5)
Leeward fascia: -60.5 psf (GCpn = -1.0)

Components & Cladding - roof pressures

Kz = Kh (case 1) = 0.85
Base pressure (qh) = **60.5 psf**
G = 0.85

a = 3.0 ft
a^2 = 9.0 sf
$4a^2$ = 36.0 sf

	Effective Wind Area	Clear Wind Flow zone 3 positive	zone 3 negative	zone 2 positive	zone 2 negative	zone 1 positive	zone 1 negative
C_N	≤ 9 sf	2.40	-3.30	1.80	-1.70	1.20	-1.10
	>9, ≤ 36 sf	1.80	-1.70	1.80	-1.70	1.20	-1.10
	> 36 sf	1.20	-1.10	1.20	-1.10	1.20	-1.10
Wind pressure	≤ 9 sf	123.5 psf	-169.7 psf	92.6 psf	-87.4 psf	61.7 psf	-56.6 psf
	>9, ≤ 36 sf	92.6 psf	-87.4 psf	92.6 psf	-87.4 psf	61.7 psf	-56.6 psf
	> 36 sf	61.7 psf	-56.6 psf	61.7 psf	-56.6 psf	61.7 psf	-56.6 psf

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JOB NO. 202100162 SHEET NO.
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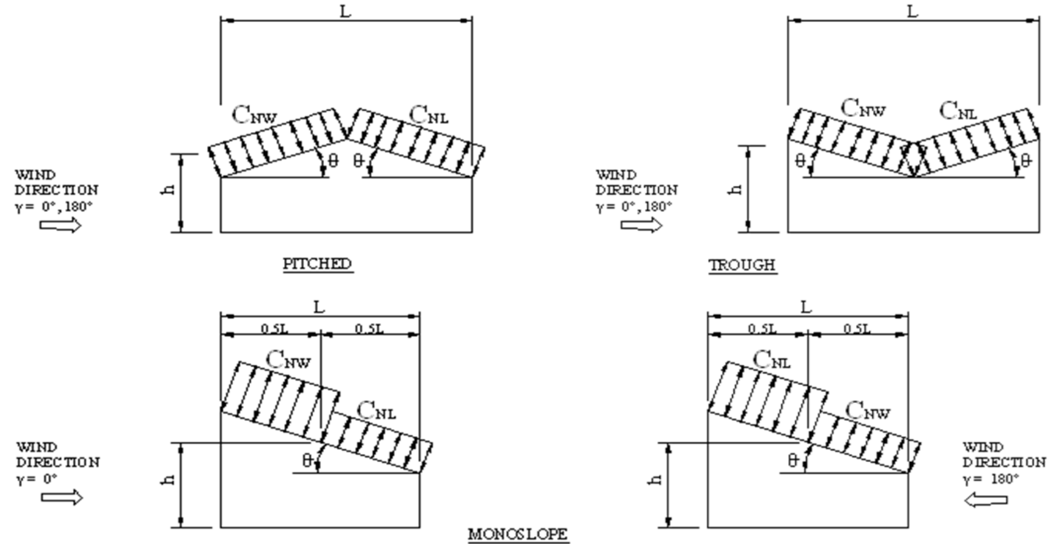
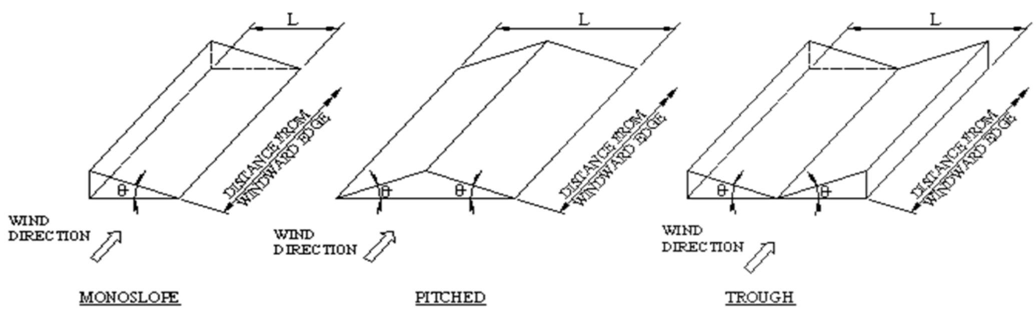
Location of Wind Pressure Zones

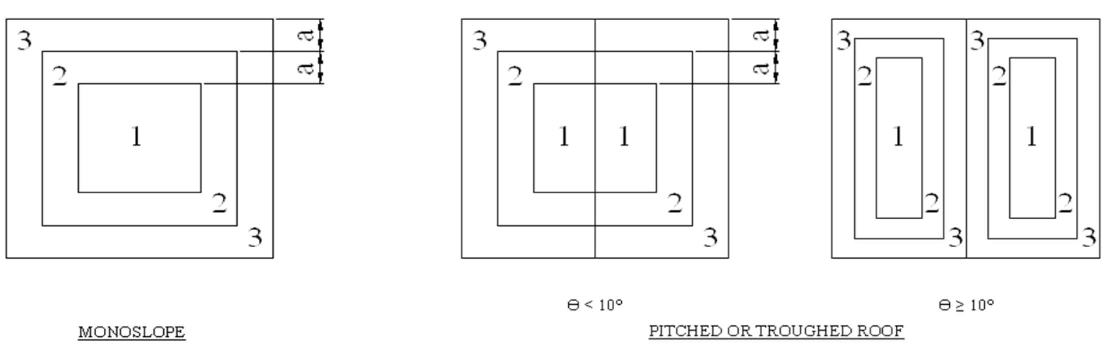


WIND DIRECTION $\gamma = 0°, 180°$



WIND DIRECTION $\gamma = 90°$

MAIN WIND FORCE RESISTING SYSTEM



COMPONENTS AND CLADDING

DESIGN CALCULATIONS

Methodology:

When checking **Knotwood™** Products (slats, posts, etc.), the applied loads, generated from ASCE 7-16, are compared to allowable tension and shear strengths per the Aluminum Design Manual.

The pergola is considered to be the "support frame". A uniform live load of 20 psf and a concentrated load of 200 lbs is applied directly to frame members. For wind loading the pergola is considered to be an "Open Structure".

Miscellaneous:

The drawings and models shown within the calculation sheets are not meant to be used for fabrication nor performing work. During the design process, elements change, and we do not change the CAD drawings in this booklet. They are for illustrative purposes only to assist in the preparation of the calculations and may not accurately represent the actual work to be performed. The contractor shall refer to the actual drawings to perform all their work.

Fastener Requirements:

Self-Tapping Metal Screws - #10 Minimum.
Galvanized Unless Noted Otherwise
Aluminum Where Noted At High/Salt Exposure
Lag Screws for Aluminum to Wood

Materials Requirements:

Knotwood Pergola Battens:
Aluminum Alloy 6063-T6: Fy=25 ksi (MIN) Fu=30 ksi (MIN)

Material Allowable Stress:

Per the ADM Table 2-21, square and rectangular tubing are not subject to lateral-torsional buckling.

Allowable Bending Stress per ADM:

$F_{ab6063} := 15.2\ ksi$

Shear Stress:

$S_{2x2} := \frac{(1.97 - 2\ (0.071))}{0.071} = 25.746$ Use: $F_{av2x2} := 9.1\ ksi$ (2x2 Batten)

$S_{2x4} := \frac{(3.94 - 2\ (0.0984))}{0.0984} = 38.041$ Use: $F_{av2x4} := 9.1\ ksi$ (2x4 Batten)

$S_{2x6} := \frac{(5.89 - 2\ (0.0984))}{0.0984} = 57.858$ Use: $F_{av2x6} := 11.5\ ksi - 0.062\ ksi \cdot S_{2x6} = 7.913\ ksi$ (2x6 Batten)

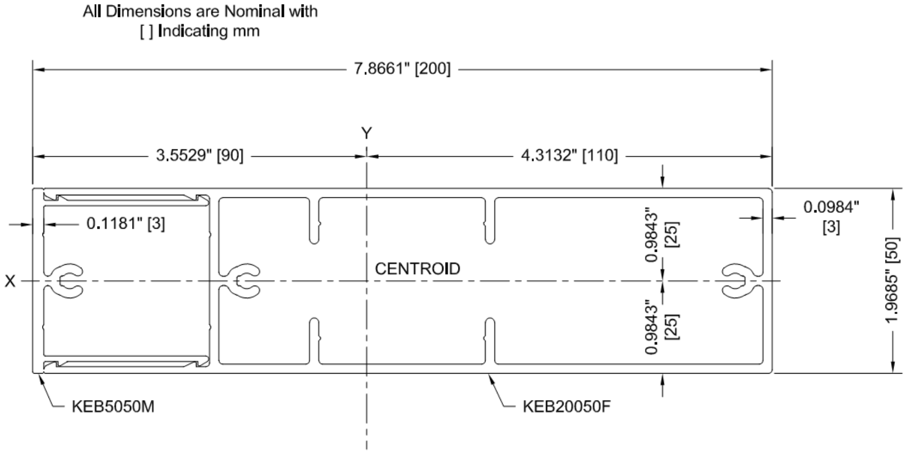
$S_{2x8} := \frac{(7.89 - 2\ (0.0984))}{0.0984} = 78.183$ Use: $F_{av2x8} := \frac{38665\ ksi}{{S_{2x8}}^2} = 6.325\ ksi$ (2x8 Batten)

Modulus of Elasticity:

$E := 10100\ ksi$

Material Section Properties:

2x8 Batten (KEB20050):



$I_{xB50200} := 1.6747\ in^4$ (Ix found per AutoCAD) $I_{yB50200} := 17.8302\ in^4$ (Iyy found per AutoCAD)

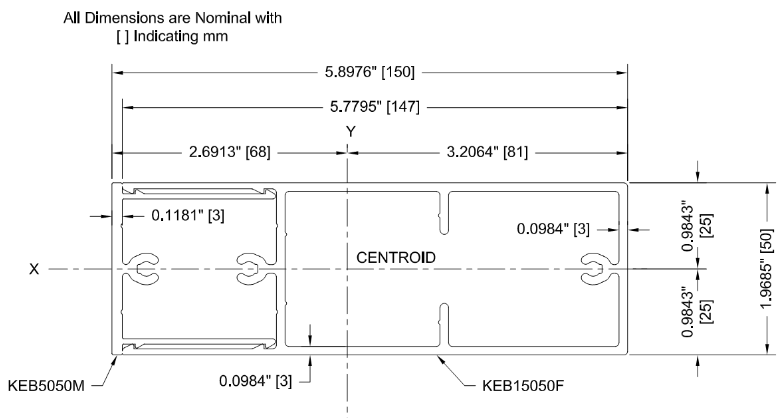
$y_{xB50200} := 0.9843\ in$ $y_{yB50200} := 4.3132\ in$

$S_{xB50200} := \frac{I_{xB50200}}{y_{xB50200}} = 1.701\ in^3$ $S_{yB50200} := \frac{I_{yB50200}}{y_{yB50200}} = 4.134\ in^3$

$A_{webB50200x} := 7.87\ in \cdot 0.0984\ in = 0.774\ in^2$ $A_{webB50200y} := 1.97\ in \cdot 0.0984\ in = 0.194\ in^2$

$A_{B50200} := 2.684\ in^2$

2x6 Batten (KEB15050):



$I_{xB50150} := 1.293\ in^4$ (Ix found per AutoCAD) $I_{yB50150} := 8.5186\ in^4$ (Iyy found per AutoCAD)

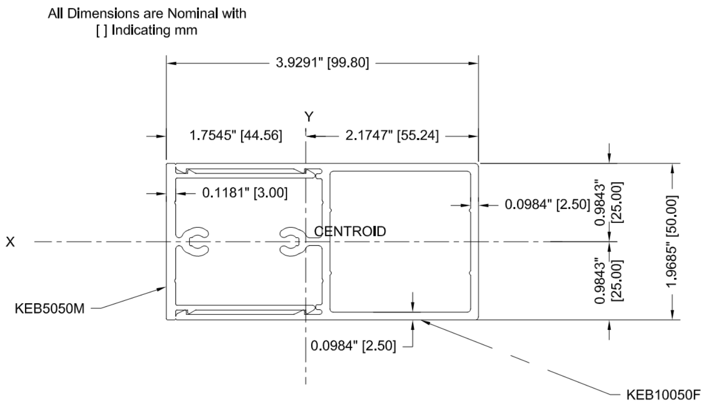
$y_{xB50150} := 0.9843\ in$ $y_{yB50150} := 3.2064\ in$

$S_{xB50150} := \frac{I_{xB50150}}{y_{xB50150}} = 1.314\ in^3$ $S_{yB50150} := \frac{I_{yB50150}}{y_{yB50150}} = 2.657\ in^3$

$A_{webB50150x} := 5.89\ in \cdot 0.0984\ in = 0.58\ in^2$ $A_{webB50150y} := 1.97\ in \cdot 0.0984\ in = 0.194\ in^2$

$A_{B50150} := 2.2028\ in^2$

2x4 Batten (KEB10050):



$I_{xB50100} := 0.9136\ in^4$ (Ix found per AutoCAD) $I_{yB50100} := 2.7236\ in^4$ (Iyy found per AutoCAD)

$y_{xB50100} := 0.9843\ in$

$y_{yB50100} := 2.1747\ in$

$S_{xB50100} := \dfrac{I_{xB50100}}{y_{xB50100}} = 0.928\ in^3$

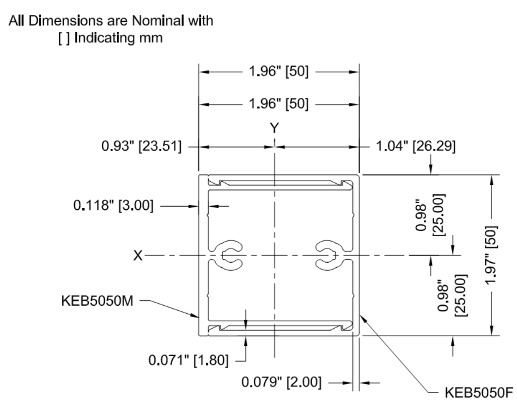
$S_{yB50100} := \dfrac{I_{yB50100}}{y_{yB50100}} = 1.252\ in^3$

$A_{webB50100x} := 3.93\ in \cdot 0.1\ in = 0.393\ in^2$

$A_{webB50100y} := 1.97\ in \cdot 0.1\ in = 0.197\ in^2$

$A_{B50100} := 872\ mm^2 = 1.352\ in^2$

2x2 Batten (KEB5050):



$I_{xB5050} := 0.5152\ in^4$ (Ixx found per AutoCAD) $I_{yB5050} := 0.5362\ in^4$ (Iyy found per AutoCAD)

$y_{xB5050} := 25\ mm = 0.984\ in$

$y_{yB5050} := 1.04\ in$

$S_{xB5050} := \dfrac{I_{xB5050}}{y_{xB5050}} = 0.523\ in^3$

$S_{yB5050} := \dfrac{I_{yB5050}}{y_{yB5050}} = 0.516\ in^3$

$S_{xB5050} = 0.523\ in^3$

$S_{yB5050} = 0.516\ in^3$

$A_{B5050} := 668\ mm^2 = 1.035\ in^2$

$A_{webB5050x} := 50\ mm \cdot 0.071\ in = 0.14\ in^2$

$A_{webB5050y} := 50\ mm \cdot 0.071\ in = 0.14\ in^2$

DESIGN CALCULATIONS

Load Requirements:

Dead Load:

$DL_{selfKEGR20050} := 3.953\ \frac{kgf}{m} = 2.656\ plf$ (Self weight of 2x8 Beam)

$DL_{selfB5050A} := 0.924\ \frac{kgf}{m} = 0.621\ plf$ (Self weight of 2x Batten Piece A)

$DL_{selfB50200B} := 3.752\ \frac{kgf}{m} = 2.521\ plf$ (Self weight of 2x8 Batten Piece B)

$DL_{selfB50150B} := 2.913\ \frac{kgf}{m} = 1.957\ plf$ (Self weight of 2x6 Batten Piece B)

$DL_{selfB50100B} := 1.95\ \frac{kgf}{m} = 1.31\ plf$ (Self weight of 2x4 Batten Piece B)

$DL_{selfB5050B} := 0.88\ \frac{kgf}{m} = 0.591\ plf$ (Self weight of 2x2 Batten Piece B)

$DL_{selfB50200} := DL_{selfB5050A} + DL_{selfB50200B} = 3.142\ plf$ (Combined self weight of 2x8 Batten Pieces)

$DL_{selfB50150} := DL_{selfB5050A} + DL_{selfB50150B} = 2.578\ plf$ (Combined self weight of 2x6 Batten Pieces)

$DL_{selfB50100} := DL_{selfB5050A} + DL_{selfB50100B} = 1.931\ plf$ (Combined self weight of 2x4 Batten Pieces)

$DL_{selfB5050} := DL_{selfB5050A} + DL_{selfB5050B} = 1.212\ plf$ (Combined self weight of 2x2 Batten Pieces)

Live Loads:

$P_{req} := 200\ lbf$ (Point Load)

$p_{LL} := 20\ psf$ (Dist. Load)

Wind Loads:

$p_{Wind} := 91\ psf$ (Max Wind Lateral Pressure - Windward Fascia)

$p_{WindDownward} := 93\ psf$ (Positive Wind Downward Pressure - Zone 3)

$p_{WindUplift} := 88\ psf$ (Negative Wind Uplift Pressure - Zone 3)

Snow Loads:

$p_g := 25\ psf$ (Ground Snow Load)

Due to open nature of structure, snow load combinations not shown in checks below as wind loads will control. This does not apply for any snow load higher than 50 psf.

Seismic Loads:

Due to low dead loads of aluminum, the seismic loads are neglected as wind loads will control over seismic.

Check 2x8 Batten (KEB20050F/KEB5050M - 6063-T6):

$L_b := 18.5\ ft$ Max Unbraced Length

$L_{bC} := 3\ ft$ Max Cantilever Length

$d_b := 8\ in$ Depth of Member

$s_b := 12\ in$ Tributary Width on Member (effective wind width)

Loading:

$w_{DLTotal} := DL_{selfB50200} + 2.5\ psf \cdot s_b = 5.642\ plf$ Total Distributed Dead Load (Including additional Metal Roof on Top)

$w_{LLTotal} := p_{LL} \cdot s_b = 20\ plf$ Total Distributed Live Load

$P_{req} = 200\ lbf$ Point Load

$w_{WLLateral} := p_{Wind} \cdot d_b = 60.667\ plf$ Ultimate Distributed Lateral Wind Load

$w_{WLDown} := p_{WindDownward} \cdot s_b = 93\ plf$ Ultimate Distributed Positive Wind Load (Considering 0% Open)

$w_{WLUplift} := p_{WindUplift} \cdot s_b = 88\ plf$ Ultimate Distributed Uplift Wind Load (Considering 0% Open)

Max moments considering beam "pinned"

DL+LL Load Case:

Distributed Loads

$$M_{1P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{P_{req} \cdot L_b}{4} = 1.166\ kip \cdot ft$$

$$V_{1P} := \frac{w_{DLTotal} \cdot L_b}{2} + P_{req} = 0.252\ kip$$

$$M_{1PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + P_{req} \cdot L_{bC} = 0.625\ kip \cdot ft$$

$$V_{1PC} := w_{DLTotal} \cdot L_{bC} + P_{req} = 0.217\ kip$$

Concentrated Load

$$M_{1D} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{w_{LLTotal} \cdot L_b^2}{8} = 1.097\ kip \cdot ft$$

$$V_{1D} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{w_{LLTotal} \cdot L_b}{2} = 0.237\ kip$$

$$M_{1DC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{w_{LLTotal} \cdot L_{bC}^2}{2} = 0.115\ kip \cdot ft$$

$$V_{1DC} := w_{DLTotal} \cdot L_{bC} + w_{LLTotal} \cdot L_{bC} = 0.077\ kip$$

DL+0.75LL+0.45WL Load Case (Worst Case Positive Wind Load):

Distributed Loads

$$M_{2P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} + \frac{0.75\ P_{req} \cdot L_b}{4} = 2.726\ kip \cdot ft$$

$$V_{2P} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} + 0.75 \cdot P_{req} = 0.589\ kip$$

$$M_{2PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} + 0.75 \cdot P_{req} \cdot L_{bC} = 0.664\ kip \cdot ft$$

$$V_{2PC} := w_{DLTotal} \cdot L_{bC} + 0.45\ w_{WLDown} \cdot L_{bC} + 0.75\ P_{req} = 0.292\ kip$$

Concentrated Load

$$M_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} = 2.432\ kip \cdot ft$$

$$V_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} = 0.526\ kip$$

$$M_{2DC} := \frac{0.75\ w_{LLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} = 0.256\ kip \cdot ft$$

$$V_{2DC} := 0.75\ w_{LLTotal} \cdot L_{bC} + 0.45\ w_{WLLateral} \cdot L_{bC} = 0.127\ kip$$

DL+0.60WL Load Case (Worst Case Lateral Load):

Distributed Loads

$$M_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b^{\ 2}}{8} = 1.557 \ kip \cdot ft$$

$$V_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.337 \ kip$$

$$M_{LateralC} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\ 2}}{2} = 0.164 \ kip \cdot ft$$

$$V_{LateralC} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.109 \ kip$$

Concentrated Load

N/A for this load combination

DL+0.60WL Load Case (Positive Vertical Wind Load):

Distributed Loads

$$M_3 := \frac{w_{DLTotal} \cdot L_b^{\ 2}}{8} + 0.60 \cdot \frac{w_{WLDown} \cdot L_b^{\ 2}}{8} = 2.629 \ kip \cdot ft$$

$$V_3 := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.337 \ kip$$

$$M_{3C} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\ 2}}{2} = 0.164 \ kip \cdot ft$$

$$V_{3C} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.109 \ kip$$

Concentrated Load

N/A for this load combination

-0.6DL+0.60WL Load Case (Uplift):

Distributed Loads

$$M_{Uplift} := -0.6 \ \frac{w_{DLTotal} \cdot L_b^{\ 2}}{8} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b^{\ 2}}{8} = 2.114 \ kip \cdot ft$$

$$V_{Uplift} := -0.6 \cdot \frac{w_{DLTotal} \cdot L_b}{2} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b}{2} = 0.457 \ kip$$

Concentrated Load

N/A for this load combination

Max Forces:

$$M_{MAX} := \max\left(M_{1P}, M_{1D}, M_{1PC}, M_{1DC}, M_{2P}, M_{2D}, M_{2PC}, M_{2DC}, M_3, M_{3C}, M_{Uplift}\right) = 2.726 \ kip \cdot ft$$

$$V_{MAX} := \max\left(V_{1P}, V_{1D}, V_{1PC}, V_{1DC}, V_{2P}, V_{2D}, V_{2PC}, V_{2DC}, V_3, V_{3C}, V_{Uplift}\right) = 0.589 \ kip$$

Check Batten Shear:

$$f_v := \frac{V_{MAX}}{2 \cdot A_{webB50200y}} = 1.52 \ ksi$$

$f_v = 1.52 \ ksi < F_{av2x8} = 6.325 \ ksi$ $\therefore =$ "OK"

Check Batten Bending:

Strong axis bending:

$$f_b := \frac{M_{MAX}}{S_{yB50200}} = 7.912 \ ksi$$

$f_b = 7.912 \ ksi < F_{ab6063} = 15.2 \ ksi$ $\therefore =$ "OK"

Weak axis bending:

$$f_{b2} := \frac{M_{Lateral}}{S_{xB50200}} = 10.983 \ ksi$$

$f_{b2} = 10.983 \ ksi < F_{ab6063} = 15.2 \ ksi$ $\therefore =$ "OK"

Check Batten Deflection:

Check deflection considering a maximum of l/60 per IBC Table 1604.3 for aluminum structural members not supporting edge of glass or aluminum sandwich panels:

$$\Delta_{LL2x8} := \frac{P_{req} \cdot L_b^{\,3}}{48 \cdot E \cdot I_{xB50200}} = 2.695 \ \mathbf{in} \qquad < \qquad \frac{L_b}{60} = 3.7 \ \mathbf{in}$$

$$\Delta_{WL2x8} := \frac{0.6 \;\, 5 \cdot w_{WLDown} \cdot L_b^{\,4}}{384 \cdot E \cdot I_{yB50200}} = 0.817 \ \mathbf{in} \qquad < \qquad \frac{L_b}{60} = 3.7 \ \mathbf{in}$$

Therefore, A max span of 18'-6" is Acceptable for a 2x8 Knotwood Batten With a Max Batten Spacing of 1'-0" at Any Location

Check Batten Fasteners (Applies for when attaching to typical pergola w/ double Knotwood Beams):

Allowable Connection Shear:

The allowable connection shear is determined according to Section J.5.6, which specifies a safety factor Ω = 3.0 for fastener connection shear for building-type structures.

$\Omega := 3.0$ — ASD building-type structures

$D := 0.19\ in$ — Fastener Diameter

$t_1 := 0.118\ in$ — Thickness of part in contact with screw head

$t_2 := 0.118\ in$ — Thickness of part not in contact with screw head

$T_{fastener} := \dfrac{V_{Uplift}}{4} = 114.272\ lbf$ — Max tension in single fastener

$V_{fastener} := \dfrac{V_{MAX}}{4} = 147.326\ lbf$ — Max shear in single fastener

Section J.5.6.1 addresses bearing. Since the edge distance is 1.0 in. > 0.42 in. = 2D, the allowable bearing force is 2FtuDt/W. Using Ftu from Table A.3.4, the allowable shear for bearing is:

$F_{tu} := 30\ ksi$ $\quad F_{ty} := 25\ ksi$ $\quad$ (Table A.3.4 - 6063-T6 aluminum clip)

$$F_{bearing} := \frac{2 \cdot F_{tu} \cdot D \cdot t_1}{\Omega} = 448\ lbf \quad > \quad V_{fastener} = 147\ lbf \ \therefore\ \text{OK}$$

Fastener Pull Over:

Nominal Pull-over Strength per ADM (Using #10 hex washer head at Minimum):

$$R_{nov} := 1.0 \cdot t_1 \cdot F_{tu} \cdot (0.414\ in - 0.147\ in) = 945.18\ lbf \qquad \text{(ADM Eq. J.5-8)}$$

Allowable Pull-over Strength:

$$F_{pullover} := \frac{R_{nov}}{\Omega} = 315.06\ lbf \quad > \quad T_{fastener} = 114.272\ lbf.\ \text{OK}$$

Fastener Shear:

$F_{vu} := 2\ kip$ — Fastener Ultimate Shear

$$F_{shear} := \frac{F_{vu}}{\Omega} = 666.667\ lbf \quad > \quad V_{fastener} = 147\ lbf \qquad \therefore\ \text{OK}$$

Fastener Tension:

Nominal Pullout (ADM J.5.5 - Assume attaching to 6063-T6 aluminum at a minimum)

$F_{ty2} := 25\ ksi$ — Yield Strength of Member not in contact with screw head

$D = 0.19\ in$ — Nominal diameter of screw

$L_e := t_2 = 0.118\ in$ — Screw engaged length w/ part not in contact with screw head

$R_n := 1.2 \cdot D \cdot L_e \cdot F_{ty2} = 673\ lbf$ — Fastener Ultimate Pullout - (ADM Eq. J.5-1)

$$F_{pullout} := \frac{R_n}{\Omega} = 224.2\ lbf \quad > \quad T_{fastener} = 114\ lbf \ \therefore\ \text{OK}$$

Therefore, use of (4) #10 Screws is acceptable

Check 2x6 Batten (KEB15050F/KEB5050M - 6063-T6):

$L_b := 18.5\ ft$ Max Unbraced Length

$L_{bC} := 2\ ft$ Max Cantilever Length

$d_b := 6\ in$ Depth of Member

$s_b := 12\ in$ Tributary Width on Member (effective wind width)

Loading:

$w_{DLTotal} := DL_{selfB50150} + 2.5\ psf \cdot s_b = 5.078\ plf$ Total Distributed Dead Load (Including additional Metal Roof on Top)

$w_{LLTotal} := p_{LL} \cdot s_b = 20\ plf$ Total Distributed Live Load

$P_{req} = 200\ lbf$ Point Load

$w_{WLLateral} := p_{Wind} \cdot d_b = 45.5\ plf$ Ultimate Distributed Lateral Wind Load

$w_{WLDown} := p_{WindDownward} \cdot s_b = 93\ plf$ Ultimate Distributed Positive Wind Load (Considering 0% Open)

$w_{WLUplift} := p_{WindUplift} \cdot s_b = 88\ plf$ Ultimate Distributed Uplift Wind Load (Considering 0% Open)

Max moments considering beam "pinned"

DL+LL Load Case:

Distributed Loads

$$M_{1P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{P_{req} \cdot L_b}{4} = 1.142\ kip \cdot ft$$

$$V_{1P} := \frac{w_{DLTotal} \cdot L_b}{2} + P_{req} = 0.247\ kip$$

$$M_{1PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + P_{req} \cdot L_{bC} = 0.41\ kip \cdot ft$$

$$V_{1PC} := w_{DLTotal} \cdot L_{bC} + P_{req} = 0.21\ kip$$

Concentrated Load

$$M_{1D} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{w_{LLTotal} \cdot L_b^2}{8} = 1.073\ kip \cdot ft$$

$$V_{1D} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{w_{LLTotal} \cdot L_b}{2} = 0.232\ kip$$

$$M_{1DC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{w_{LLTotal} \cdot L_{bC}^2}{2} = 0.05\ kip \cdot ft$$

$$V_{1DC} := w_{DLTotal} \cdot L_{bC} + w_{LLTotal} \cdot L_{bC} = 0.05\ kip$$

DL+0.75LL+0.45WL Load Case (Worst Case Positive Wind Load):

Distributed Loads

$$M_{2P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} + \frac{0.75\ P_{req} \cdot L_b}{4} = 2.701\ kip \cdot ft$$

$$V_{2P} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} + 0.75 \cdot P_{req} = 0.584\ kip$$

$$M_{2PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} + 0.75 \cdot P_{req} \cdot L_{bC} = 0.394\ kip \cdot ft$$

$$V_{2PC} := w_{DLTotal} \cdot L_{bC} + 0.45\ w_{WLDown} \cdot L_{bC} + 0.75\ P_{req} = 0.244\ kip$$

Concentrated Load

$$M_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} = 2.432\ kip \cdot ft$$

$$V_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} = 0.526\ kip$$

$$M_{2DC} := \frac{0.75\ w_{LLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} = 0.114\ kip \cdot ft$$

$$V_{2DC} := 0.75\ w_{LLTotal} \cdot L_{bC} + 0.45\ w_{WLLateral} \cdot L_{bC} = 0.071\ kip$$

DESIGN CALCULATIONS

DL+0.60WL Load Case (Worst Case Lateral Load):

Distributed Loads

$$M_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b^{\,2}}{8} = 1.168 \ \boldsymbol{kip \cdot ft}$$

$$V_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.253 \ \boldsymbol{kip}$$

$$M_{LateralC} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\,2}}{2} = 0.055 \ \boldsymbol{kip \cdot ft}$$

$$V_{LateralC} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.055 \ \boldsymbol{kip}$$

Concentrated Load

N/A for this load combination

DL+0.60WL Load Case (Positive Vertical Wind Load):

Distributed Loads

$$M_3 := \frac{w_{DLTotal} \cdot L_b^{\,2}}{8} + 0.60 \cdot \frac{w_{WLDown} \cdot L_b^{\,2}}{8} = 2.604 \ \boldsymbol{kip \cdot ft}$$

$$V_3 := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.253 \ \boldsymbol{kip}$$

$$M_{3C} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\,2}}{2} = 0.055 \ \boldsymbol{kip \cdot ft}$$

$$V_{3C} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.055 \ \boldsymbol{kip}$$

Concentrated Load

N/A for this load combination

-0.6DL+0.60WL Load Case (Uplift):

Distributed Loads

$$M_{Uplift} := -0.6 \ \frac{w_{DLTotal} \cdot L_b^{\,2}}{8} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b^{\,2}}{8} = 2.128 \ \boldsymbol{kip \cdot ft}$$

$$V_{Uplift} := -0.6 \cdot \frac{w_{DLTotal} \cdot L_b}{2} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b}{2} = 0.46 \ \boldsymbol{kip}$$

Concentrated Load

N/A for this load combination

Max Forces:

$$M_{MAX} := \max\left(M_{1P}, M_{1D}, M_{1PC}, M_{1DC}, M_{2P}, M_{2D}, M_{2PC}, M_{2DC}, M_3, M_{3C}, M_{Uplift}\right) = 2.701 \ \boldsymbol{kip \cdot ft}$$

$$V_{MAX} := \max\left(V_{1P}, V_{1D}, V_{1PC}, V_{1DC}, V_{2P}, V_{2D}, V_{2PC}, V_{2DC}, V_3, V_{3C}, V_{Uplift}\right) = 0.584 \ \boldsymbol{kip}$$

Check Batten Shear:

$$f_v := \frac{V_{MAX}}{2 \cdot A_{webB50150y}} = 1.507 \ \boldsymbol{ksi}$$

$$f_v = 1.507 \ \boldsymbol{ksi} < F_{av2x6} = 7.913 \ \boldsymbol{ksi} \quad \therefore = \text{“OK”}$$

Check Batten Bending:

Strong axis bending:

$$f_b := \frac{M_{MAX}}{S_{yB50150}} = 12.202 \ \boldsymbol{ksi}$$

$$f_b = 12.202 \ \boldsymbol{ksi} < F_{ab6063} = 15.2 \ \boldsymbol{ksi} \quad \therefore = \text{“OK”}$$

Weak axis bending:

$$f_{b2} := \frac{M_{Lateral}}{S_{xB50150}} = 10.669 \ \boldsymbol{ksi}$$

$$f_{b2} = 10.669 \ \boldsymbol{ksi} < F_{ab6063} = 15.2 \ \boldsymbol{ksi} \quad \therefore = \text{“OK”}$$

Check Batten Deflection:

Check deflection considering a maximum of l/60 per IBC Table 1604.3 for aluminum structural members not supporting edge of glass or aluminum sandwich panels:

$$\Delta_{LL2x6} := \frac{P_{req} \cdot L_b^{\ 3}}{48 \cdot E \cdot I_{xB50150}} = 3.491\ in \qquad < \qquad \frac{L_b}{60} = 3.7\ in$$

$$\Delta_{WL2x6} := \frac{0.6\ 5 \cdot w_{WLDown} \cdot L_b^{\ 4}}{384 \cdot E \cdot I_{yB50150}} = 1.709\ in \qquad < \qquad \frac{L_b}{60} = 3.7\ in$$

Therefore, A max span of 18'-6" is Acceptable for a 2x6 Knotwood Batten With a Max Batten Spacing of 1'-0" at Any Location

Check Batten Fasteners (Applies for when attaching to typical pergola w/ double Knotwood Beams):

Allowable Connection Shear:

The allowable connection shear is determined according to Section J.5.6, which specifies a safety factor Ω = 3.0 for fastener connection shear for building-type structures.

$\Omega := 3.0$ — ASD building-type structures

$D := 0.19\ in$ — Fastener Diameter

$t_1 := 0.118\ in$ — Thickness of part in contact with screw head

$t_2 := 0.118\ in$ — Thickness of part not in contact with screw head

$T_{fastener} := \dfrac{V_{Uplift}}{4} = 115.054\ lbf$ — Max tension in single fastener

$V_{fastener} := \dfrac{V_{MAX}}{4} = 146.022\ lbf$ — Max shear in single fastener

Section J.5.6.1 addresses bearing. Since the edge distance is 1.0 in. > 0.42 in. = 2D, the allowable bearing force is 2FtuDt/W. Using Ftu from Table A.3.4, the allowable shear for bearing is:

$F_{tu} := 30\ ksi$ $\quad F_{ty} := 25\ ksi$ (Table A.3.4 - 6063-T6 aluminum clip)

$$F_{bearing} := \frac{2 \cdot F_{tu} \cdot D \cdot t_1}{\Omega} = 448\ lbf \quad > \quad V_{fastener} = 146\ lbf \ \therefore \text{ OK}$$

Fastener Pull Over:

Nominal Pull-over Strength per ADM (Using #10 hex washer head at Minimum):

$$R_{nov} := 1.0 \cdot t_1 \cdot F_{tu} \cdot (0.414\ in - 0.147\ in) = 945.18\ lbf \qquad \text{(ADM Eq. J.5-8)}$$

Allowable Pull-over Strength:

$$F_{pullover} := \frac{R_{nov}}{\Omega} = 315.06\ lbf \quad > \quad T_{fastener} = 115.054\ lbf. \text{ OK}$$

Fastener Shear:

$F_{vu} := 2\ kip$ — Fastener Ultimate Shear

$$F_{shear} := \frac{F_{vu}}{\Omega} = 666.667\ lbf \ > \ V_{fastener} = 146\ lbf \qquad \therefore \text{ OK}$$

Fastener Tension:

Nominal Pullout (ADM J.5.5 - Assume attaching to 6063-T6 aluminum at a minimum)

$F_{ty2} := 25\ ksi$ — Yield Strength of Member not in contact with screw head

$D = 0.19\ in$ — Nominal diameter of screw

$L_e := t_2 = 0.118\ in$ — Screw engaged length w/ part not in contact with screw head

$R_n := 1.2 \cdot D \cdot L_e \cdot F_{ty2} = 673\ lbf$ — Fastener Ultimate Pullout - (ADM Eq. J.5-1)

$$F_{pullout} := \frac{R_n}{\Omega} = 224.2\ lbf \quad > \ T_{fastener} = 115\ lbf \ \therefore \text{ OK}$$

Therefore, use of (4) #10 Screws is acceptable

Check 2x4 Batten (KEB10050F/KEB5050M - 6063-T6):

$L_b := 13.5\ ft$ Max Unbraced Length

$L_{bC} := 2\ ft$ Max Cantilever Length

$d_b := 4\ in$ Depth of Member

$s_b := 12\ in$ Tributary Width on Member (effective wind width)

Loading:

$w_{DLTotal} := DL_{selfB50150} + 2.5\ psf \cdot s_b = 5.078\ plf$ Total Distributed Dead Load (Including additional Metal Roof on Top)

$w_{LLTotal} := p_{LL} \cdot s_b = 20\ plf$ Total Distributed Live Load

$P_{req} = 200\ lbf$ Point Load

$w_{WLLateral} := p_{Wind} \cdot d_b = 30.333\ plf$ Ultimate Distributed Lateral Wind Load

$w_{WLDown} := p_{WindDownward} \cdot s_b = 93\ plf$ Ultimate Distributed Positive Wind Load (Considering 0% Open)

$w_{WLUplift} := p_{WindUplift} \cdot s_b = 88\ plf$ Ultimate Distributed Uplift Wind Load (Considering 0% Open)

Max moments considering beam "pinned"

DL+LL Load Case:

Distributed Loads

$$M_{1P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{P_{req} \cdot L_b}{4} = 0.791\ kip \cdot ft$$

$$V_{1P} := \frac{w_{DLTotal} \cdot L_b}{2} + P_{req} = 0.234\ kip$$

$$M_{1PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + P_{req} \cdot L_{bC} = 0.41\ kip \cdot ft$$

$$V_{1PC} := w_{DLTotal} \cdot L_{bC} + P_{req} = 0.21\ kip$$

Concentrated Load

$$M_{1D} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{w_{LLTotal} \cdot L_b^2}{8} = 0.571\ kip \cdot ft$$

$$V_{1D} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{w_{LLTotal} \cdot L_b}{2} = 0.169\ kip$$

$$M_{1DC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{w_{LLTotal} \cdot L_{bC}^2}{2} = 0.05\ kip \cdot ft$$

$$V_{1DC} := w_{DLTotal} \cdot L_{bC} + w_{LLTotal} \cdot L_{bC} = 0.05\ kip$$

DL+0.75LL+0.45WL Load Case (Worst Case Positive Wind Load):

Distributed Loads

$$M_{2P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} + \frac{0.75\ P_{req} \cdot L_b}{4} = 1.575\ kip \cdot ft$$

$$V_{2P} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} + 0.75 \cdot P_{req} = 0.467\ kip$$

$$M_{2PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} + 0.75 \cdot P_{req} \cdot L_{bC} = 0.394\ kip \cdot ft$$

$$V_{2PC} := w_{DLTotal} \cdot L_{bC} + 0.45\ w_{WLDown} \cdot L_{bC} + 0.75\ P_{req} = 0.244\ kip$$

Concentrated Load

$$M_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} = 1.295\ kip \cdot ft$$

$$V_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} = 0.384\ kip$$

$$M_{2DC} := \frac{0.75\ w_{LLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} = 0.114\ kip \cdot ft$$

$$V_{2DC} := 0.75\ w_{LLTotal} \cdot L_{bC} + 0.45\ w_{WLLateral} \cdot L_{bC} = 0.057\ kip$$

DL+0.60WL Load Case (Worst Case Lateral Load):

Distributed Loads

$$M_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b^{\,2}}{8} = 0.415 \ kip \cdot ft$$

$$V_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.123 \ kip$$

$$M_{LateralC} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\,2}}{2} = 0.036 \ kip \cdot ft$$

$$V_{LateralC} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.036 \ kip$$

Concentrated Load

N/A for this load combination

DL+0.60WL Load Case (Positive Vertical Wind Load):

Distributed Loads

$$M_3 := \frac{w_{DLTotal} \cdot L_b^{\,2}}{8} + 0.60 \cdot \frac{w_{WLDown} \cdot L_b^{\,2}}{8} = 1.387 \ kip \cdot ft$$

$$V_3 := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.123 \ kip$$

$$M_{3C} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\,2}}{2} = 0.036 \ kip \cdot ft$$

$$V_{3C} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.036 \ kip$$

Concentrated Load

N/A for this load combination

-0.6DL+0.60WL Load Case (Uplift):

Distributed Loads

$$M_{Uplift} := -0.6 \ \frac{w_{DLTotal} \cdot L_b^{\,2}}{8} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b^{\,2}}{8} = 1.133 \ kip \cdot ft$$

$$V_{Uplift} := -0.6 \cdot \frac{w_{DLTotal} \cdot L_b}{2} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b}{2} = 0.336 \ kip$$

Concentrated Load

N/A for this load combination

Max Forces:

$$M_{MAX} := \max\left(M_{1P}, M_{1D}, M_{1PC}, M_{1DC}, M_{2P}, M_{2D}, M_{2PC}, M_{2DC}, M_3, M_{3C}, M_{Uplift}\right) = 1.575 \ kip \cdot ft$$

$$V_{MAX} := \max\left(V_{1P}, V_{1D}, V_{1PC}, V_{1DC}, V_{2P}, V_{2D}, V_{2PC}, V_{2DC}, V_3, V_{3C}, V_{Uplift}\right) = 0.467 \ kip$$

Check Batten Shear:

$$f_v := \frac{V_{MAX}}{2 \cdot A_{webB50100y}} = 1.185 \ ksi$$

$$f_v = 1.185 \ ksi < F_{av2x4} = 9.1 \ ksi \quad \therefore = \text{“OK”}$$

Check Batten Bending:

Strong axis bending:

$$f_b := \frac{M_{MAX}}{S_{yB50100}} = 15.094 \ ksi$$

$$f_b = 15.094 \ ksi < F_{ab6063} = 15.2 \ ksi \quad \therefore = \text{“OK”}$$

Weak axis bending:

$$f_{b2} := \frac{M_{Lateral}}{S_{xB50100}} = 5.36 \ ksi$$

$$f_{b2} = 5.36 \ ksi < F_{ab6063} = 15.2 \ ksi \quad \therefore = \text{“OK”}$$

Check Batten Deflection:

Check deflection considering a maximum of l/60 per IBC Table 1604.3 for aluminum structural members not supporting edge of glass or aluminum sandwich panels:

$$\Delta_{LL2x6} := \frac{P_{req} \cdot L_b^{\ 3}}{48 \cdot E \cdot I_{xB50100}} = 1.92\ \textit{in} \qquad < \qquad \frac{L_b}{60} = 2.7\ \textit{in}$$

$$\Delta_{WL2x6} := \frac{0.6\ 5 \cdot w_{WLDown} \cdot L_b^{\ 4}}{384 \cdot E \cdot I_{yB50100}} = 1.516\ \textit{in} \qquad < \qquad \frac{L_b}{60} = 2.7\ \textit{in}$$

Therefore, A max span of 13'-6" is Acceptable for a 2x4 Knotwood Batten With a Max Batten Spacing of 1'-0" at Any Location

Check Batten Fasteners (Applies for when attaching to typical pergola w/ double Knotwood Beams):

Allowable Connection Shear:

The allowable connection shear is determined according to Section J.5.6, which specifies a safety factor Ω = 3.0 for fastener connection shear for building-type structures.

$\Omega := 3.0$ ASD building-type structures

$D := 0.19\ in$ Fastener Diameter

$t_1 := 0.118\ in$ Thickness of part in contact with screw head

$t_2 := 0.118\ in$ Thickness of part not in contact with screw head

$T_{fastener} := \frac{V_{Uplift}}{4} = 83.958\ lbf$ Max tension in single fastener

$V_{fastener} := \frac{V_{MAX}}{4} = 116.692\ lbf$ Max shear in single fastener

Section J.5.6.1 addresses bearing. Since the edge distance is 1.0 in. > 0.42 in. = 2D, the allowable bearing force is 2FtuDt/W. Using Ftu from Table A.3.4, the allowable shear for bearing is:

$F_{tu} := 30\ ksi$ $F_{ty} := 25\ ksi$ (Table A.3.4 - 6063-T6 aluminum clip)

$F_{bearing} := \frac{2 \cdot F_{tu} \cdot D \cdot t_1}{\Omega} = 448\ lbf$ > $V_{fastener} = 117\ lbf$ $\therefore$ OK

Fastener Pull Over:

Nominal Pull-over Strength per ADM (Using #10 hex washer head at Minimum):

$R_{nov} := 1.0 \cdot t_1 \cdot F_{tu} \cdot (0.414\ in - 0.147\ in) = 945.18\ lbf$ (ADM Eq. J.5-8)

Allowable Pull-over Strength:

$F_{pullover} := \frac{R_{nov}}{\Omega} = 315.06\ lbf$ > $T_{fastener} = 83.958\ lbf$ $\therefore$ OK

Fastener Shear:

$F_{vu} := 2\ kip$ Fastener Ultimate Shear

$F_{shear} := \frac{F_{vu}}{\Omega} = 666.667\ lbf$ > $V_{fastener} = 117\ lbf$ $\therefore$ OK

Fastener Tension:

Nominal Pullout (ADM J.5.5 - Assume attaching to 6063-T6 aluminum at a minimum)

$F_{ty2} := 25\ ksi$ Yield Strength of Member not in contact with screw head

$D = 0.19\ in$ Nominal diameter of screw

$L_e := t_2 = 0.118\ in$ Screw engaged length w/ part not in contact with screw head

$R_n := 1.2 \cdot D \cdot L_e \cdot F_{ty2} = 673\ lbf$ Fastener Ultimate Pullout - (ADM Eq. J.5-1)

$F_{pullout} := \frac{R_n}{\Omega} = 224.2\ lbf$ > $T_{fastener} = 84\ lbf$ $\therefore$ OK

Therefore, use of (4) #10 Screws is acceptable

Check 2x2 Batten (KEB5050F/KEB5050M - 6063-T6):

$L_b := 7.5\ ft$ Max Unbraced Length

$L_{bC} := 2\ ft$ Max Cantilever Length

$d_b := 2\ in$ Depth of Member

$s_b := 12\ in$ Tributary Width on Member (effective wind width)

Loading:

$w_{DLTotal} := DL_{selfB50150} + 2.5\ psf \cdot s_b = 5.078\ plf$ Total Distributed Dead Load (Including additional Metal Roof on Top)

$w_{LLTotal} := p_{LL} \cdot s_b = 20\ plf$ Total Distributed Live Load

$P_{req} = 200\ lbf$ Point Load

$w_{WLLateral} := p_{Wind} \cdot d_b = 15.167\ plf$ Ultimate Distributed Lateral Wind Load

$w_{WLDown} := p_{WindDownward} \cdot s_b = 93\ plf$ Ultimate Distributed Positive Wind Load (Considering 0% Open)

$w_{WLUplift} := p_{WindUplift} \cdot s_b = 88\ plf$ Ultimate Distributed Uplift Wind Load (Considering 0% Open)

Max moments considering beam "pinned"

DL+LL Load Case:

Distributed Loads

$$M_{1P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{P_{req} \cdot L_b}{4} = 0.411\ kip \cdot ft$$

$$V_{1P} := \frac{w_{DLTotal} \cdot L_b}{2} + P_{req} = 0.219\ kip$$

$$M_{1PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + P_{req} \cdot L_{bC} = 0.41\ kip \cdot ft$$

$$V_{1PC} := w_{DLTotal} \cdot L_{bC} + P_{req} = 0.21\ kip$$

Concentrated Load

$$M_{1D} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{w_{LLTotal} \cdot L_b^2}{8} = 0.176\ kip \cdot ft$$

$$V_{1D} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{w_{LLTotal} \cdot L_b}{2} = 0.094\ kip$$

$$M_{1DC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{w_{LLTotal} \cdot L_{bC}^2}{2} = 0.05\ kip \cdot ft$$

$$V_{1DC} := w_{DLTotal} \cdot L_{bC} + w_{LLTotal} \cdot L_{bC} = 0.05\ kip$$

DL+0.75LL+0.45WL Load Case (Worst Case Positive Wind Load):

Distributed Loads

$$M_{2P} := \frac{w_{DLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} + \frac{0.75\ P_{req} \cdot L_b}{4} = 0.611\ kip \cdot ft$$

$$V_{2P} := \frac{w_{DLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} + 0.75 \cdot P_{req} = 0.326\ kip$$

$$M_{2PC} := \frac{w_{DLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} + 0.75 \cdot P_{req} \cdot L_{bC} = 0.394\ kip \cdot ft$$

$$V_{2PC} := w_{DLTotal} \cdot L_{bC} + 0.45\ w_{WLDown} \cdot L_{bC} + 0.75\ P_{req} = 0.244\ kip$$

Concentrated Load

$$M_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b^2}{8} + \frac{0.45\ w_{WLDown} \cdot L_b^2}{8} = 0.4\ kip \cdot ft$$

$$V_{2D} := \frac{0.75\ w_{LLTotal} \cdot L_b}{2} + \frac{0.45\ w_{WLDown} \cdot L_b}{2} = 0.213\ kip$$

$$M_{2DC} := \frac{0.75\ w_{LLTotal} \cdot L_{bC}^2}{2} + \frac{0.45\ w_{WLDown} \cdot L_{bC}^2}{2} = 0.114\ kip \cdot ft$$

$$V_{2DC} := 0.75\ w_{LLTotal} \cdot L_{bC} + 0.45\ w_{WLLateral} \cdot L_{bC} = 0.044\ kip$$

DL+0.60WL Load Case (Worst Case Lateral Load):

Distributed Loads

$$M_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b^{\,2}}{8} = 0.064 \ \mathbf{kip \cdot ft}$$

$$V_{Lateral} := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.034 \ \mathbf{kip}$$

$$M_{LateralC} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\,2}}{2} = 0.018 \ \mathbf{kip \cdot ft}$$

$$V_{LateralC} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.018 \ \mathbf{kip}$$

Concentrated Load

N/A for this load combination

DL+0.60WL Load Case (Positive Vertical Wind Load):

Distributed Loads

$$M_3 := \frac{w_{DLTotal} \cdot L_b^{\,2}}{8} + 0.60 \cdot \frac{w_{WLDown} \cdot L_b^{\,2}}{8} = 0.428 \ \mathbf{kip \cdot ft}$$

$$V_3 := 0.60 \cdot \frac{w_{WLLateral} \cdot L_b}{2} = 0.034 \ \mathbf{kip}$$

$$M_{3C} := \frac{0.6 \ w_{WLLateral} \cdot L_{bC}^{\,2}}{2} = 0.018 \ \mathbf{kip \cdot ft}$$

$$V_{3C} := 0.6 \ w_{WLLateral} \cdot L_{bC} = 0.018 \ \mathbf{kip}$$

Concentrated Load

N/A for this load combination

-0.6DL+0.60WL Load Case (Uplift):

Distributed Loads

$$M_{Uplift} := -0.6 \ \frac{w_{DLTotal} \cdot L_b^{\,2}}{8} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b^{\,2}}{8} = 0.35 \ \mathbf{kip \cdot ft}$$

$$V_{Uplift} := -0.6 \cdot \frac{w_{DLTotal} \cdot L_b}{2} + 0.60 \cdot \frac{w_{WLUplift} \cdot L_b}{2} = 0.187 \ \mathbf{kip}$$

Concentrated Load

N/A for this load combination

Max Forces:

$$M_{MAX} := \max\left(M_{1P}, M_{1D}, M_{1PC}, M_{1DC}, M_{2P}, M_{2D}, M_{2PC}, M_{2DC}, M_3, M_{3C}, M_{Uplift}\right) = 0.611 \ \mathbf{kip \cdot ft}$$

$$V_{MAX} := \max\left(V_{1P}, V_{1D}, V_{1PC}, V_{1DC}, V_{2P}, V_{2D}, V_{2PC}, V_{2DC}, V_3, V_{3C}, V_{Uplift}\right) = 0.326 \ \mathbf{kip}$$

Check Batten Shear:

$$f_v := \frac{V_{MAX}}{2 \cdot A_{webB5050y}} = 1.166 \ \mathbf{ksi}$$

$$f_v = 1.166 \ \mathbf{ksi} < F_{av2x2} = 9.1 \ \mathbf{ksi} \quad \therefore = \text{“OK”}$$

Check Batten Bending:

Strong axis bending:

$$f_b := \frac{M_{MAX}}{S_{yB5050}} = 14.226 \ \mathbf{ksi}$$

$$f_b = 14.226 \ \mathbf{ksi} < F_{ab6063} = 15.2 \ \mathbf{ksi} \quad \therefore = \text{“OK”}$$

Weak axis bending:

$$f_{b2} := \frac{M_{Lateral}}{S_{xB5050}} = 1.467 \ \mathbf{ksi}$$

$$f_{b2} = 1.467 \ \mathbf{ksi} < F_{ab6063} = 15.2 \ \mathbf{ksi} \quad \therefore = \text{“OK”}$$

Check Batten Deflection:

Check deflection considering a maximum of l/60 per IBC Table 1604.3 for aluminum structural members not supporting edge of glass or aluminum sandwich panels:

$$\Delta_{LL2x6} := \frac{P_{req} \cdot L_b^{\ 3}}{48 \cdot E \cdot I_{xB5050}} = 0.584\ \boldsymbol{in} \qquad < \qquad \frac{L_b}{60} = 1.5\ \boldsymbol{in}$$

$$\Delta_{WL2x6} := \frac{0.6\ 5 \cdot w_{WLDown} \cdot L_b^{\ 4}}{384 \cdot E \cdot I_{yB5050}} = 0.734\ \boldsymbol{in} \qquad < \qquad \frac{L_b}{60} = 1.5\ \boldsymbol{in}$$

Therefore, A max span of 7'-6" is Acceptable for a 2x2 Knotwood Batten With a Max Batten Spacing of 1'-0" at Any Location

Check Batten Fasteners (Applies for when attaching to typical pergola w/ double Knotwood Beams):

Allowable Connection Shear:

The allowable connection shear is determined according to Section J.5.6, which specifies a safety factor Ω = 3.0 for fastener connection shear for building-type structures.

$\Omega := 3.0$ ASD building-type structures

$D := 0.19\ in$ Fastener Diameter

$t_1 := 0.118\ in$ Thickness of part in contact with screw head

$t_2 := 0.118\ in$ Thickness of part not in contact with screw head

$T_{fastener} := \frac{V_{Uplift}}{4} = 46.643\ lbf$ Max tension in single fastener

$V_{fastener} := \frac{V_{MAX}}{4} = 81.495\ lbf$ Max shear in single fastener

Section J.5.6.1 addresses bearing. Since the edge distance is 1.0 in. > 0.42 in. = 2D, the allowable bearing force is 2FtuDt/W. Using Ftu from Table A.3.4, the allowable shear for bearing is:

$F_{tu} := 30\ ksi$ $F_{ty} := 25\ ksi$ (Table A.3.4 - 6063-T6 aluminum clip)

$F_{bearing} := \frac{2 \cdot F_{tu} \cdot D \cdot t_1}{\Omega} = 448\ lbf$ > $V_{fastener} = 81\ lbf$ $\therefore$ OK

Fastener Pull Over:

Nominal Pull-over Strength per ADM (Using #10 hex washer head at Minimum):

$R_{nov} := 1.0 \cdot t_1 \cdot F_{tu} \cdot (0.414\ in - 0.147\ in) = 945.18\ lbf$ (ADM Eq. J.5-8)

Allowable Pull-over Strength:

$F_{pullover} := \frac{R_{nov}}{\Omega} = 315.06\ lbf$ > $T_{fastener} = 46.643\ lbf$ $\therefore$ OK

Fastener Shear:

$F_{vu} := 2\ kip$ Fastener Ultimate Shear

$F_{shear} := \frac{F_{vu}}{\Omega} = 666.667\ lbf$ > $V_{fastener} = 81\ lbf$ $\therefore$ OK

Fastener Tension:

Nominal Pullout (ADM J.5.5 - Assume attaching to 6063-T6 aluminum at a minimum)

$F_{ty2} := 25\ ksi$ Yield Strength of Member not in contact with screw head

$D = 0.19\ in$ Nominal diameter of screw

$L_e := t_2 = 0.118\ in$ Screw engaged length w/ part not in contact with screw head

$R_n := 1.2 \cdot D \cdot L_e \cdot F_{ty2} = 673\ lbf$ Fastener Ultimate Pullout - (ADM Eq. J.5-1)

$F_{pullout} := \frac{R_n}{\Omega} = 224.2\ lbf$ > $T_{fastener} = 47\ lbf$ $\therefore$ OK

Therefore, use of (4) #10 Screws is acceptable

DESIGN CALCULATIONS

Design Summary:

Below is the summary of the max spans for Knotwood pergola battens based on loading above. Due to generic nature of these calculations, worst case loading conditions are considered with an assumed metal decking roof attached to the battens with a maximum spacing of 1'-0" between the battens to put maximum load on the battens. Furthermore, a worst case wind load condition is applied based on Exposure C with a 181 mph Ultimate wind speed. Any situation outside of these maximum loading conditions shall be designed for by the EOR.

Note: 18'-6" is max length available for Knotwood battens.

2x8 Battens (KEB20050F + KEB5050M)

Max Span: 18'-6" @ Max 1'-0" Batten Spacing

2x6 Battens (KEB15050F + KEB5050M)

Max Span: 18'-6" @ Max 1'-0" Batten Spacing

2x4 Battens (KEB10050F + KEB5050M)

Max Span: 13'-6" @ Max 1'-0" Batten Spacing

2x2 Battens (KEB5050F + KEB5050M)

Max Span: 7'-6" @ Max 1'-0" Batten Spacing

APPENDIX 'A'
(TECHNICAL & PRODUCT DATA SHEETS)

Please be advised, the product data sheets contained in this appendix are included in this submission for their load capacities only, which are referenced in the attached calculations. PVE does not mandate that the contractor must use the exact products manufactured by the companies listed on said product data sheets. The contractor may substitute for any of the products contained in this appendix provided that the substituted products are equivalent or better than those listed in this appendix

FROM ALUMINUM DESIGN MANUAL

Table 2-21
ALLOWABLE STRESSES F/Ω (k/in^2) FOR BUILDING-TYPE STRUCTURES (UNWELDED)

6063 - T6 B221, B241, B429 0.000 to 1.000 in. thick

Axial Tension	Section	F/Ω
axial tension stress on net effective area	D.2b	15.4
axial tension stress on gross area	D.2a	15.2
Shear or torsion		
Shear or torsion rupture	G, H.2	9.2
Bearing		
bolts or rivets on holes	J.3.6a, J.4.6	30.8
bolts on slots, pins on holes, flat surfaces	J.3.6b, J.6.5, J.8	20.5
screws in holes	J.5.5.1	20.0

F_{ty} = 25 k/in^2

F_{cy} = 25 k/in^2

F_{tu} = 30 k/in^2

E = 10,100 k/in^2

k_t = 1

	Section	λ	F/Ω for $\lambda \le \lambda_1$	λ_1	F/Ω for $\lambda_1 < \lambda < \lambda_2$	λ_2	F/Ω for $\lambda \ge \lambda_2$
Axial Compression - member buckling	E.2	kL/r	15.2	18.2	$0.00022\lambda^2 - 0.133\lambda + 17.5$	78	$51{,}352/\lambda^2$
Flexure - lateral-torsional buckling	F.4	see F.4.2		-	see F.4	78	$60{,}414/\lambda^2$
Elements - Uniform Compression							
flat elements supported on one edge in columns whose buckling axis is not an axis of symmetry	B.5.4.1	b/t	15.2	7.3	$19.0 - 0.530\lambda$	15	$2{,}417/\lambda^2$
flat elements supported on one edge in all other columns and all beams	B.5.4.1	b/t	15.2	7.3	$19.0 - 0.530\lambda$	12.6	$155/\lambda$
flat elements supported on both edges	B.5.4.2	b/t	15.2	22.8	$19.0 - 0.170\lambda$	39	$484/\lambda$
flat elements supported on both edges and with an intermediate stiffener	B.5.4.4	λ_s	15.2	18.2	$16.7 - 0.088\lambda$	78	$60{,}414/\lambda^2$
round hollow elements	B.5.4.5	R_b/t	15.2	31.2	$18.5 - 0.593\lambda^{1/2}$	189	$3{,}776/(\lambda k_n)$†
flat elements - direct strength method	B.5.4.6	λ_{eq}	15.2	36.5	$19.0 - 0.106\lambda$	63	$775/\lambda$
Elements - Flexural Compression							
flat elements supported on both edges	B.5.5.1	b/t	22.7	34.7	$27.9 - 0.150\lambda$	93	$1{,}298/\lambda$
flat elements supported on tension edge, compression edge free	B.5.5.2	b/t	22.7	6.5	$27.9 - 0.810\lambda$	23	$4{,}932/\lambda^2$
flat elements supported on both edges and with a longitudinal stiffener	B.5.5.3	b/t	22.7	77.8	$27.9 - 0.067\lambda$	208	$2{,}910/\lambda$
pipes and round tubes	B.5.5.4	R_b/t	$27.7 - 1.70\lambda^{1/2}$	70.0	$18.5 - 0.593\lambda^{1/2}$	189	$3{,}776/(\lambda k_n)$†
flat elements - direct strength method	B.5.5.5	λ_{eq}	M_{np}/S_{xc}	36.5	see B.5.5.5	74	$696/\lambda$
Elements - Shear							
flat elements supported on both edges	G.2	b/t	9.1	38.7	$11.5 - 0.062\lambda$	76	$38{,}665/\lambda^2$
flat elements supported on one edge	G.3	b/t	9.1	16.1	$11.5 - 0.150\lambda$	32	$6{,}713/\lambda^2$
pipes and round or oval tubes	G.4	λ_p*	9.1	72.2	$15.0 - 0.081\lambda$	76	$50{,}264/\lambda^2$
Torsion - pipes and round or oval tubes	H.2.1	λ_p*	9.1	38.7	$11.5 - 0.062\lambda$	76	$38{,}665/\lambda^2$

*$\lambda_p = 2.9(R_b/t)^{5/8}(L/R_b)^{1/4}$

†$k_n = (1+\lambda^{1/2}/35)^2$