SITE CRITERIA AND LOADS ON STRUCTURE

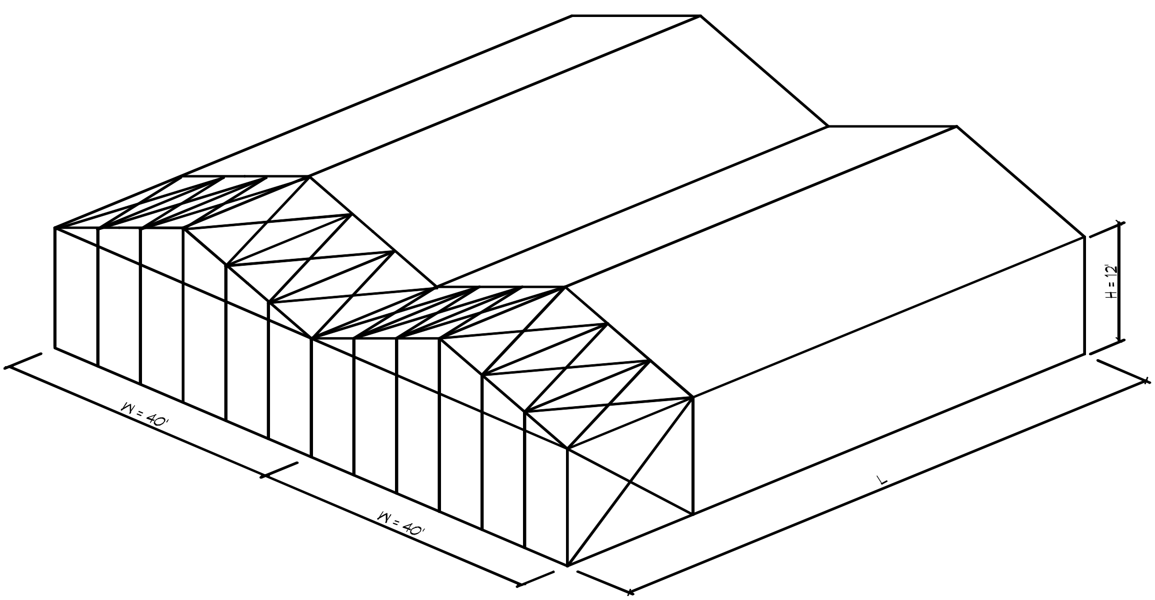
CODE	**ASCE 7-98** / *IBC 2000*	Note, references to **ASCE 7-98** are bold, references to *IBC 2000* are in italics.

SITE CRITERIA:

Roof Live Load	10 psf	*IBC 1607.11.2.1*
Roof Dead Load	5 psf (assumed)	
Ground Snow	30 psf	Site specific information, **Figure 7-1**
Basic Wind Speed	90 mph, Exposure C	Site specific information, **Figure 6-1**
Seismic Site Class	D	Default value per **9.4.1.2.1** (exception)
Occupancy Category	I	**Table 1-1** This is for a production type greenhouse that is not highly occupied. Commercial greenhouses, used for retail purposes, would be in category II. A commercial greenhouse would use a higher I-value for wind and snow design. It does not affect seismic design.
Seismic Use Group	I	**Table 9.1.3** and section **9.1.3** Seismic Use Group is based on the occupancy category of the structure. Occupancy categories I and II are both Seismic Use Group I.
Mapped Earthquake Ground Motion	$S_s = 0.5g$ $S_1 = 0.18g$	Site specific information from maps, figures **9.4.1.1(a)** and **9.4.1.1(b)**

Example building:

Gutter connected production greenhouse
40 ft span, symmetrical



CONSTRUCTION DOCUMENTS
ITEMS TO BE SHOWN ON PLANS

Per *IBC Section 1603*		**Example Building:**		
Floor Live Load	*1603.1.1*	N/A		
Roof Live Load	*1603.1.2*	10 psf		
Roof Snow Load	*1603.1.3*			
1. Flat-roof snow load, Pf		p_f =	18.5	psf
2. Snow exposure factor, Ce		C_e =	1.0	
3. Snow load importance factor, I		I =	0.8	
4. Thermal factor, Ct		C_t =	1.1	
Wind Load	*1603.1.4*			
1. Basic wind speed		V =	90	mph
2. Wind importance factor, I		I =	0.87	
and building category		I		
3. Wind exposure		C		
4. Applicable internal pressure coefficient		+ 0.18	Enclosed building	
		- 0.18		
5. Components and cladding		Provide design wind pressure to be used in design of exterior component and cladding materials not specifically designed by the registered design professional.		
Earthquake Design Data	*1603.1.5*			
1. Seismic use group		I		
2. Spectral response coefficients, SDS and SD1		S_{DS} =	0.47	
		S_{D1} =	0.25	
3. Site class		D		
4. Basic seismic-force-resisting system		Ordinary concentric braced frame		
5. Design base shear		V =	0.11	*W
6. Analysis procedure		Simplified analysis		
7. Seismic importance factor, I		I_E =	1.0	
Flood Load	*1603.1.6*			
For buildings located in flood hazard areas (per 1612.3)		Example structure not located in flood zone		
Special Loads	*1603.1.7*	Per NGMA Manual		
System and components requiring special inspection for seismic resistance	*1603.1.8*	Typically not required		

SNOW DESIGN

Flat-roof snow load, p_f:

$p_f = 0.7C_eC_tIp_g$ **(Eq. 7-1)**

Where:

$p_g =$ 30 psf (**Figure 7-2**)

$C_e =$ 1.0 (**Table 7-2**, partially exposed roof)

$C_t =$ 1.1 (**Table 7-3**, structure kept just above freezing)

$I =$ 0.8 (**Table 7-4**, Category I)

$p_f =$ 18.5 psf

Sloped-roof snow load, p_s:

$p_s = C_sp_f$ (**Eq. 7-2**)

Where:

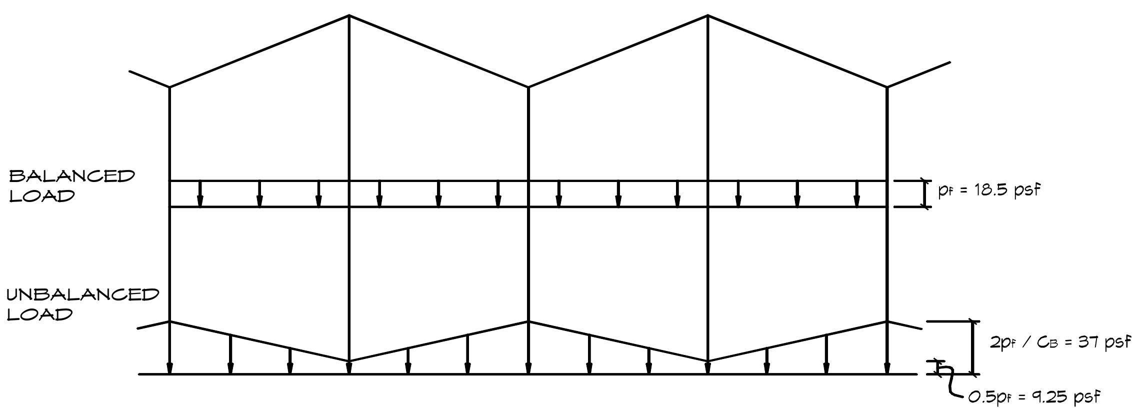
$p_f =$ 18.5 psf

$C_s =$ 1.00 (Per **7.4.4** roof slope factor for multiple folded plate, sawtooth, and barrel vault roofs $C_s = 1.0$, otherwise $C_s = 0.9$ per Figure 7-2a for a 4:12 roof slope, warm roof)

$p_s =$ 18.5 psf

There is additional snow load design required at the valley between the two portions of the structure per **7.6.3** and **Figure 7.6**.

There will be approximately twice the snow load in the valley and half the snow load at the peak as shown below.



WIND DESIGN

Assume 4:12 (18.4^o) roof slope

Velocity pressure, q_z:

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$ (psf) (**Eq. 6-13**)

Where:

K_z =	0.85	(**Table 6-5**, Exposure C, 0-15' ht)
K_{zt} =	1	(Assume no wind speed-up effects)
K_d =	0.85	(**Table 6-6**)
V =	90	mph (**Figure 6-1**)
I =	0.87	(**Table 6-1**, Category I)

q_z = 13.03 psf

Design wind pressures, *p* (**Eq. 6-15**)

p = $q(GC_{pf}) - qi(GC_{pi})$ (psf)

Where:

q = q_i =	13.0	psf (= q_z = q_h for this example)	
(GC_{pf}) =	0.53	(Figure 6-4, Case A, building surface 1 = wall, windward)	CASE A (transverse)
	-0.69	(Figure 6-4, Case A, building surface 2 = roof, windward)	CASE A (transverse)
	-0.48	(Figure 6-4, Case A, building surface 3 = roof, leeward)	CASE A (transverse)
	-0.43	(Figure 6-4, Case A, building surface 4 = wall, leeward)	CASE A (transverse)
	-0.45	(Figure 6-4, Case B, building surface 1 = wall)	CASE B (longitudinal)
	-0.69	(Figure 6-4, Case B, building surface 2 = roof)	CASE B (longitudinal)
	-0.37	(Figure 6-4, Case B, building surface 3 = roof)	CASE B (longitudinal)
	-0.45	(Figure 6-4, Case B, building surface 4 = wall)	CASE B (longitudinal)
	0.40	(Figure 6-4, Case B, building surface 5 = wall, windward)	CASE B (longitudinal)
	-0.29	(Figure 6-4, Case B, building surface 6 = wall, leeward)	CASE B (longitudinal)
(GC_{pi}) =	0.55	(**Table 6-7**, partially enclosed buildings)	
	-0.55	(**Table 6-7**, partially enclosed buildings)	
	0.18	(**Table 6-7**, enclosed buildings)	
	-0.18	(**Table 6-7**, enclosed buildings)	

Case A	Design Wind Pressure, *p* (psf)			
	Partially Enclosed		Enclosed	
	max	min	max	min
Windward:				
Wall (surface 1)	14.08	-0.26	9.25	4.56
Roof (surface 2)	-1.82	-16.16	-6.65	-11.34
Leeward:				
Roof (surface 3)	0.91	-13.43	-3.91	-8.60
Wall (surface 4)	1.56	-12.77	-3.26	-7.95

Case B	Design Wind Pressure, *p* (psf)			
	Partially Enclosed		Enclosed	
	max	min	max	min
Wall (surface 1)	1.30	-13.03	-3.52	-8.21
Roof (surface 2)	-1.82	-16.16	-6.65	-11.34
Roof (surface 3)	2.35	-11.99	-2.48	-7.17
Wall (surface 4)	1.30	-13.03	-3.52	-8.21
Windward:				
Wall (surface 5)	12.38	-1.96	7.56	2.87
Leeward:				
Wall (surface 6)	3.39	-10.95	-1.43	-6.13

Determine which wind loads to use (which govern) in load combinations:

<u>FOR AN ENCLOSED STRUCTURE:</u>

Transverse direction (Case A):

Vertical load due to wind, on roof (outward pressure)

-11.34 psf, max

Horizontal load

9.25 psf, max - windward

-7.95 psf, max - leeward

Longitudinal direction (Case B):

Vertical load due to wind, on roof (outward pressure)

-11.34 psf, max (same as vertical load due to wind in transverse direction)

Horizontal load

7.56 psf, max - windward

-6.13 psf, max - leeward

side walls:

-8.21 psf, max

FOR A PARTIALLY ENCLOSED STRUCTURE:

Transverse direction (Case A):

Vertical load due to wind, on roof (outward pressure)

-16.16 psf, max

Horizontal load

14.8 psf, max - windward

-12.77 psf, max - leeward

Longitudinal direction (Case B):

Vertical load due to wind, on roof (outward pressure)

-16.16 psf, max (same as vertical load due to wind in transverse direction)

Horizontal load

12.38 psf, max - windward

-10.95 psf, max - leeward

side walls:

-13.03 psf, max

SEISMIC DESIGN

Design per **ASCE 7 Ch. 9**

Site location: Southern Indiana
Use site location to obtain information from maps (see below)
(S_s = 0.5g See map, **Fig. 9.4.1.1(a)**)
(S_1 = 0.18g See map, **Fig. 9.4.1.1(b)**)

Site Class: D — Default value per **9.4.1.2.1** to use without site specific geotechnical investigation

Seismic Use Group: I — Agricultural facilities/temporary or storage facilities that are not essential facilities or that do not represent a substantial hazard to human life Occupancy Category II would be SUG I and would have the same seismic requirements)
Table 1-1, Table 9.1.3 and Section 9.1.3

Go to maps in ASCE-7/IBC:

9.4.1.1	S_s =	0.5	g	**Fig. 9.4.1.1(a)**	Mapped maximum considered earthquake spectral response acceleration at short periods, S_s, and at 1-second period, S_1
	S_1 =	0.18	g	**Fig. 9.4.1.1(b)**	

Calculate the mapped maximum considered earthquake spectral response accelerations:

9.4.1.2.4	S_{MS} =	F_aS_s		**Eq. 9.4.1.2.4-1**	
		Where:			
		F_a =	1.4	**Table 9.4.1.2.4a**	For Site Class D & S_s = 0.5
		S_1 =	0.5	**Fig. 9.4.1.1(a)**	
	S_{MS} =	0.7			
	S_{M1} =	F_vS_1		**Eq. 9.4.1.2.4-2**	
		Where:			
		F_v =	2.1	**Table 9.4.1.2.4b**	For Site Class D & S_1 = 0.18 (interpolate)
		S_1 =	0.18	**Fig. 9.4.1.1(b)**	
	S_{M1} =	0.378			

From this, calculate the design spectral response accelerations:

9.4.1.2.5	S_{DS} =	$2/3*S_{MS}$	**Eq. 9.4.1.2.5-1**
	S_{DS} =	0.4667	
	S_{D1} =	$2/3*S_{M1}$	**Eq. 9.4.1.2.5-2**
	S_{D1} =	0.252	

Determine building period:

9.4.1.2.6 Building period N/A (simplified design used per **9.5.2.5**)

Based on SUG = I and calculated S_{DS} and S_{D1}, determine Seismic Design Category from tables:

9.4.2 Seismic Design Category = C based on short period response acceleration

Table 9.4.2.1a For Seismic Use Group I & S_{DS} = 0.47

Seismic Design Category = D based on 1 second period response acceleration

Table 9.4.2.1b For Seismic Use Group I & S_{D1} = 0.25

Therefore, use Seismic Category = D (per **9.4.2.1**, use most severe of the two)

TABLE 9.4.2.1a. Seismic Design Category Based on Short Period Response Accelerations

	Seismic Use Group		
Value of S_{DS}	I	II	III
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D[a]	D[a]	D[a]

[a]Seismic Use Group I and II structures located on sites with mapped maximum considered earthquake spectral response acceleration at 1 s period, S_1, equal to or greater than 0.75g shall be assigned to Seismic Design Category E and Seismic Use Group III structures located on such sites shall be assigned to Seismic Design Category F.

TABLE 9.4.2.1b. Seismic Design Category Based on 1 s Period Response Accelerations

	Seismic Use Group		
Value of S_{D1}	I	II	III
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D[a]	D[a]	D[a]

[a]Seismic Use Group I and II structures located on sites with mapped maximum considered earthquake spectral response acceleration at 1 s period, S_1, equal to or greater than 0.75g shall be assigned to Seismic Design Category E and Seismic Use Group III structures located on such sites shall be assigned to Seismic Design Category F.

For complete information, see ASCE-7 or IBC

9.5.2.5 Analysis Procedures:

Simplified analysis, in accordance with **9.5.3.8**, may be used for any structure in Seismic Use Group I.

9.5.3.8 V = $((1.2\ S_{DS})/R) * W$ **Eq. 9.5.3.8.1**

Where

S_{DS} = 0.467

R = 5 **Table 9.5.2.2** Ordinary steel concentrically braced frames (Note, this would also be applicable to aluminum and light gage steel frames)

A different R-value may apply in the longitudinal than in the transverse direction depending on the lateral force resisting system. The Base Shear, V, would be different in the different directions.

V = 0.112 *W The load is applied at the eave line of the building.

Notes:

1. See also *IBC Sections 2205 and 2211* for minimum provisions for light gage steel structures. *Section 2205* references AISI Specification. The provisions of *2211.7* are for buildings assigned to seismic design category D, E, or F and include minimum design provisions for connections for diagonal bracing members, top chord splices, boundary elements and collectors. There is special design for diagonal bracing under certain conditions per *2211.7.5* .
2. Section 1617.4 IBC and 9.5.3.8 of ASCE 7, where the flat roof snow load exceeds 30 psf, twenty percent of the flat roof snow load must be included as part of the seismic weight (W).

Additional design requirements:

Reliability factor, ρ
The overall design shall include a review of the redundancy of the structure. This factor is rho, ρ, and which is multiplied times the effective seismic mass (Q_E). The factor, ρ, varies from 1.0 to 1.5. The factor may vary for each building configuration as well as Seismic Design Category. Below is a chart showing the maximum value. This may be used as the default value in many cases since wind may govern.

Overstrength factor, Ω
Specific components shall be designed for an overstrength factor, Omega, Ω. This applies to collectors, their splices and their connections to the lateral force resisting elements. This will typically be the gutters and other edge/boundary members in greenhouses. Its use is dependent on the Seismic Design Category.

Seismic Design Category	Default Factor	
	Rho, ρ	Omega, Ω (for Braced Frames)
A	1.0	-
B	1.0	-
C	1.0	2.0
D	1.5	2.0
E	1.5	2.0
F	1.5	2.0

Drift (Section **9.5.3.7.1**)
Compute the structure drift at the roof of a one story building. This must be compared to the value in **Table 9.5.2.8** for the Allowable Story Drift. The structure drift is based on the type of lateral force resisting system and uses the C_d factor obtained from **Table 9.5.2.2**.

Requirements by Seismic Design Category:

Regardless if wind governs the design or not, the lateral-force-resisting systems shall meet seismic detailing requirements and limitations prescribed in the code (*IBC 1609.1.5*)

The following are the minimum requirements for the seismic design and interconnection of building elements per **Chapter 9**:

Design basis, per **9.5.2.1**, to provide a continuous load path, or paths, to transfer all forces from the point of application to the final point of resistance.

For Seismic Design Category A **9.5.2.5.1 and 9.5.2.6.1**

Minimum seismic design provisions include consideration of the following:

Component load effects - all structure components shall have the strength to resist minimum seismic loads (**9.5.2.6.1.1**)

Load path connections - all parts of the structure shall be interconnected to form a continuous path to the seismic load-resisting system, and the connections shall be designed for seismic force F_p (**9.5.2.6.1.2**)

$F_x = 0.01\ W$	**Eq. 9.5.2.5.1**	Minimum lateral force (for design of collector element - gutter), where the weight, W, includes 20% of flat snow load where flat roof snow load exceeds 30 psf. (9.5.3.2)
$F_p = 0.05\ w$ or $0.133\ S_{DS} * w$	**9.5.2.6.1.2**	Minimum lateral load for design of connections (w is the weight of the smaller part being connected to the larger part). Note that connection of beam, girders, or truss to support is to be designed to resist 5% of the dead and live load vertical reaction applied horizontally.

Note: All structures are required to be designed for minimum requirements of Seismic Design Category A, and with further requirements based on the Seismic Design Category.

LOAD COMBINATIONS

Roof Dead Load, D =	5.0	psf
Roof Live Load, L_r =	10.0	psf (Lr < than S therefore S governs)
Snow Load, S =	18.5	psf
Wind Load, W =	13.00	psf design wind pressure
Earthquake Load, E =	0.11 W	lb, base shear

Basic Combinations - Strength Design (**Section 2.3.2**)

1. 1.4 D
2. 1.2 D + 0.5 (L_r or S or R)
3. 1.2 D + 1.6 (L_r or S or R) + 0.8 W
4. 1.2 D + 1.6 W + 0.5 (L_r or S or R)
5. 1.2 D + 1.0 E + 0.2 S
6. 0.9 D + 1.6 W
7. 0.9 D + 1.0 E

Where:
D = dead load
E = earthquake load
L_r = roof live load
R = rain load
S = snow load
W = wind load

Note: Per **2.3.3** there are additional load combinations to be considered if the structure is located in a flood zone.

Note: Roof live load, L, has not been included since for one-story greenhouse with a concrete slab floor there is none to be considered.

Allowable Stress Design - Load Combinations (**Section 2.4.1**)

1. D
2. D + (Lr or S or R)
3. D + (W or 0.7 E) + (Lr or S or R)
4. 0.6 D + W
5. 0.6 D + 0.7 E

STRUCTURE DESIGN

Roof Design:
Using Allowable Stress Design or Basic Load Combinations (Strength Design)
- Truss Analysis
- Connectors

Lateral Design (Wind and Seismic):
Using Allowable Stress Design or Basic Load Combinations (Strength Design)

PLEASE VISIT US ON THE WEB:
www. ngma.com
communications@ngma.com
4305 North Sixth Street, Suite A
Harrisburg, PA 17110
800-792-NGMA (6462)
717-238-4530 FAX 717-238-9985