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June 8th, 2017

STEP BY STEP
 PUYALLUP, WA
 USA, 98271

THE APPROVED CONSTRUCTION PLANS,
 DOCUMENTS AND ALL ENGINEERING MUST
 BE POSTED ON THE JOB AT ALL
 INSPECTIONS IN A VISIBLE AND READILY
 ACCESSIBLE LOCATION.

FULL SIZED LEDGIBLE COLOR PLANS ARE
 REQUIRED TO BE PROVIDED BY THE
 PERMITEE ON SITE FOR INSPECTION

Ref: (1) Luminosa (S9) 30' x 144' @ 12' under gutter
PJ-1644rev3, Order 184732
Step by Step greenhouses
Puyallup, WA, 98271

To whom it may concern:

We are pleased to submit to you engineering details and foundations design parameters about the greenhouse of referenced project. Please note that our 3D structural software does compute all members according to AISC 360-10 (LRFD). The modeling was done using de design criteria of International Building Code 2015 for the town of Puyallup, WA. The Luminosa S8 is a light steel structure, moment resisting frame in lateral axis, and braced resisting frame in longitudinal axis.

Please feel free to contact me for any questions.

Regards,

LES INDUSTRIES HARNOIS INC.

Carl Savard, P. Eng.



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GREENHOUSE DESIGN

**LUMINOSA S9 30' @ 12' GUTTER
(1) bay x 144' (4 320 ft²)**

**STRUCTURAL SPECIFICATIONS &
FOUNDATION DESIGN PARAMETERS**

STEP BY STEP, 2017



1- Structural description of the greenhouse.

Structural composition:

- All steel members have a minimum yield of 50 000 psi.
- All steel members tubes, arches, interior posts, are galvanized treated galvalum AZ150.
- All steel sheets, gutters, are galvanized treated Z600.
- All steel welded connector & bracket, exterior posts, are hot dipped galvanized.
- All aluminium mouldings are made with 6063-T5 or 6063-T54.
- All bolts are made with Zinc-Nickel plated steel grade 5.

Please note that our 3D structural software does compute all members according to the Limit States design standard AISC 360-10 (LRFD).

Greenhouse structures:

- Greenhouse geometry is Luminosa (S9) 30'.
- Column height under gutter is 12'.
- Exterior anchors elements are made with 3-1/2" x 3-1/2" x 0.120" spaced at 12' c/c.
- Exterior columns elements are made with 3-1/2" x 3-1/2" x 0.120" spaced at 12' c/c.
- Structural gutter is made from steel sheet of 0.138" (10GA).
- Arch elements are made with Harnois Strong Oval tubes 2" x 3-9/16" x 0.083" spaced at 6'.
- Arch unions are made with Harnois Strong Oval tubes 2" x 3-9/16" x 0.083" spaced at 6'.
- X-Bracings are made with square section of 2-1/2" with wall thickness of 0.083".
- Trusses 20" spaced at 12' c/c are made with following elements:
 - Top Chord and Bottom 1-1/2" x 2-1/2" x 0.065"
 - Web 1-1/4"SQ x 0.049"
- Trusses are longitudinally stabilised with link.
- Gable end framing are made with following elements:
 - Upright Harnois oval 1-5/8" x 2-3/4" x 0.065".
 - Links square tube of 1-1/4"SQ x 0.049".
- Gable end reinforcement is made with following elements:
 - Horizontal members made with Harnois oval 2-1/2" x 3-1/2" x 0.083".
 - Diagonal supports made with square tube of 2-1/2"SQ x 0.083".



2- Design loads basis

Loads, load combinations and safety margin were modeled based on International Building Code (IBC) 2015 and design loads criteria given by ASCE 7-10 for the city of Puyallup, WA. The risk category of the building based on customer usage was establish *RISK CATEGORY II*. For the greenhouse in reference, the following loads were applied:

Dead Load (D):

- Structure weight (all steel members, roof, gutter and systems weight).
- Cladding weight.

Snow Load (S):

- 30 psf ground snow load in accordance with ASCE 7-10. Exposure Factor of (C_e) of 1.0 and thermal factor (C_t) of 0.85 was applied for a continuously heated greenhouse (ASCE 7-10 table 7-2 & 7-3). Uniform snow load and unbalanced snow load were analysed (ASCE 7-10 figure 7-5).

Wind Load (W):

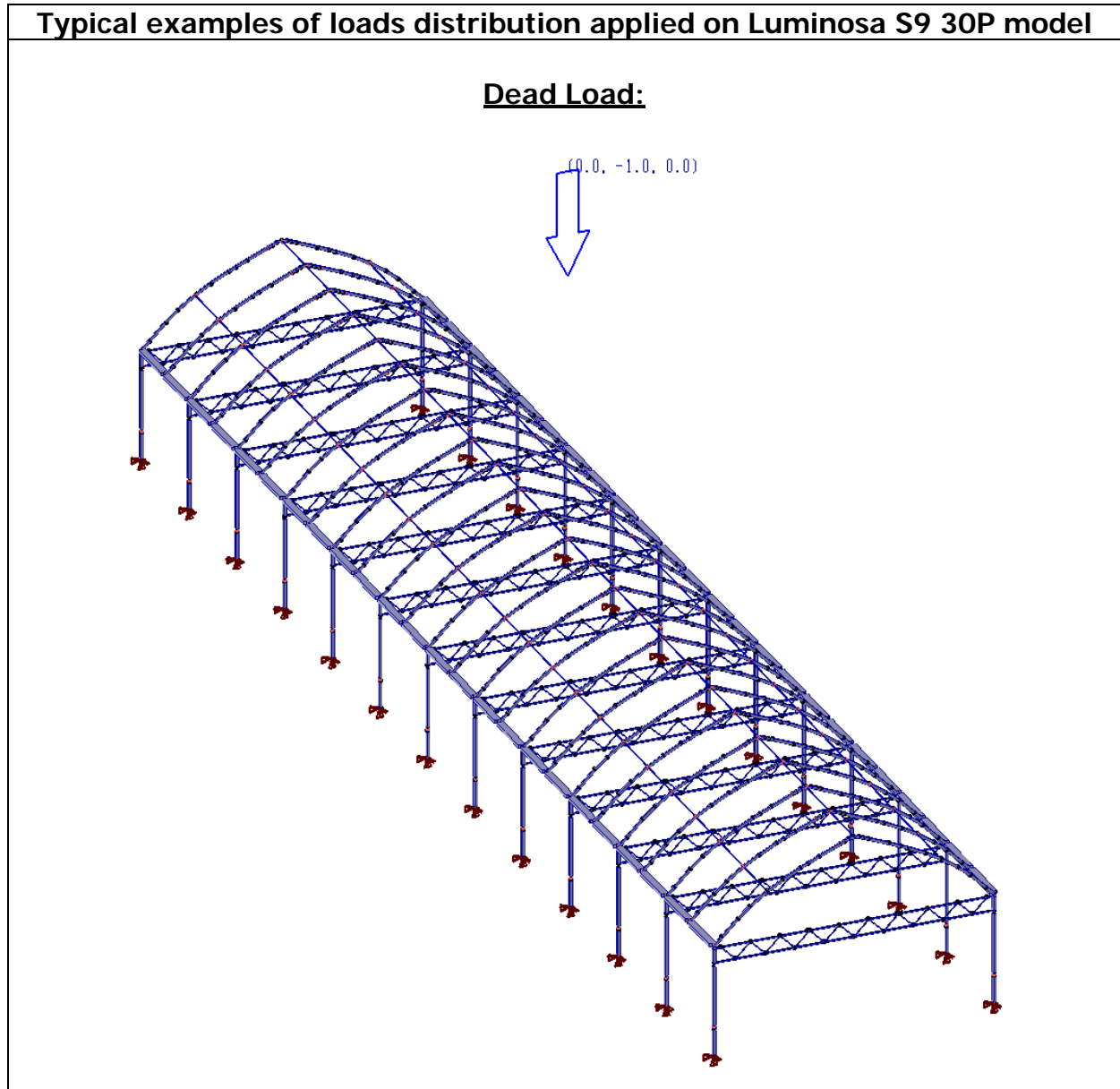
- A wind speed of 110 MPH, 3 seconds gust (ASCE 7-10, Cat II, Exposure B, Partially Enclosed building) is used to established the wind pressure (P_1 & P_2) applied on the structure. P_1/P_2 mean internal pressure is negative or positive.

Seismic Load (E):

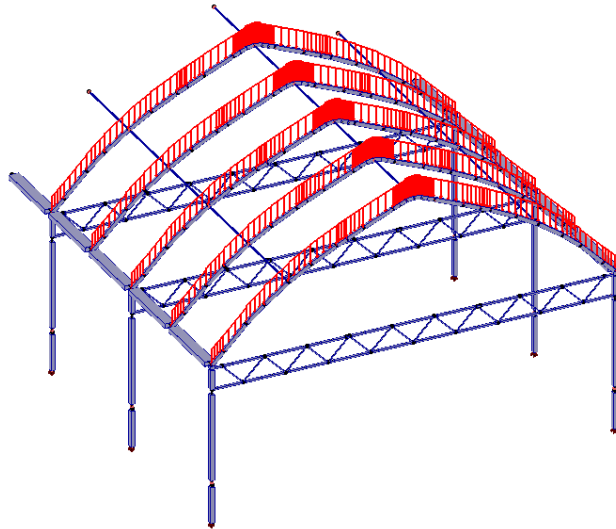
- The seismic design category (SDC) was calculated based on the design spectral response acceleration $S_{ds} = 0.834$ at site Class = D, Risk Cat II. Luminosa greenhouse is a light steel structure, moment resisting frame in lateral axis, and braced resisting frame in longitudinal axis. This greenhouse model is used accross seismic regions.

Typical Loads :

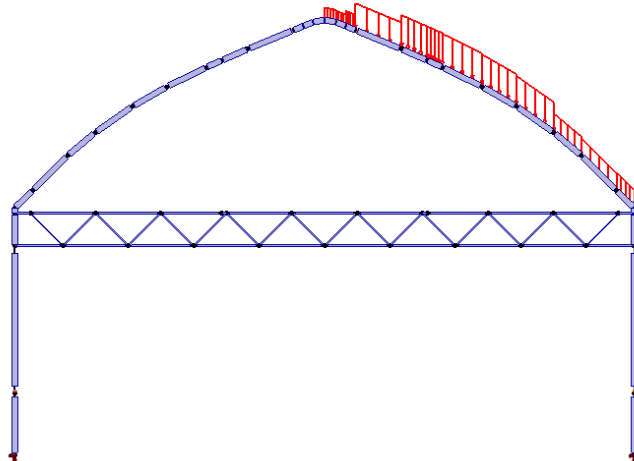
The following pictures show examples of load distribution used to determine the greenhouses design:



Uniform Snow load:



Unbalanced Snow Load:



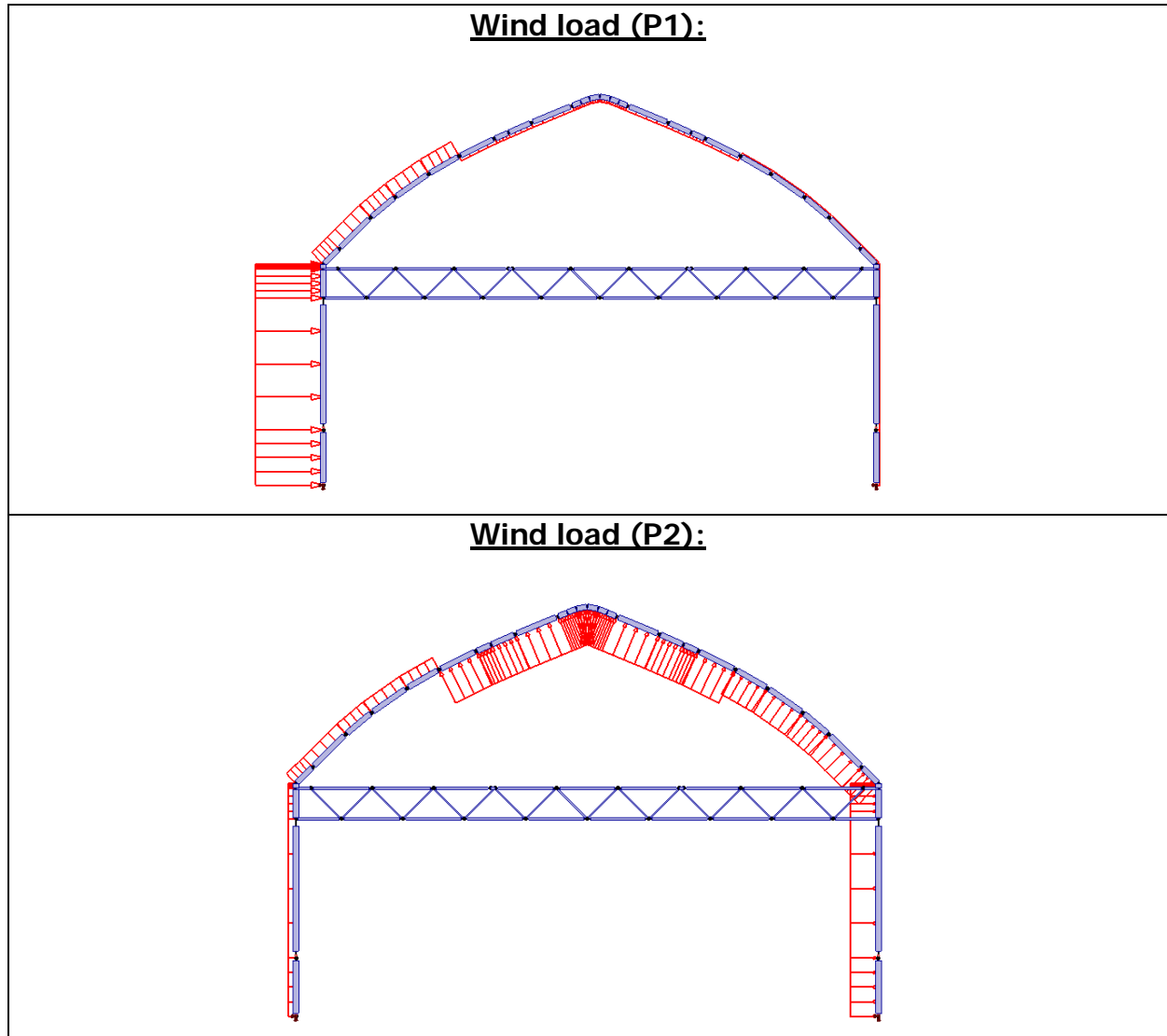


Figure 1 : Typical loads applied on greenhouse



3- Load combinations

The load combinations being used and specified by ASCE 7-10 section 2.3.2 using strength design. The following combinations were analysed:

LC 1: 1.4 (D)

LC 2: 1.2 (D) + 1.6 (S⁽¹⁾)

LC 3: 1.2 (D) + 1.6 (S) + 0.5 (W⁽²⁾)

LC 4: 1.2 (D) + 1.0 (W) + 0.5 (S)

LC 5: 1.2 (D) + 1.0 E + 0.2 (S)

LC 6: 0.9 (D) + 1.0 (W)

LC 7: 0.9 (D) + 1.0 (E)

(1) Uniform Snow Load and Unbalanced Snow Load are analyzed in all combination.

(2) W(P1) and W(P2) are analyzed in all combination.

4- Foundations design parameters

The foundations parameters is given for the load which govern the greenhouse design: the uniform snow load and wind load. The table 1 below shows **OVERALL non-factored** reactions forces:

Table 1: Overall reactions forces non-factored

Load combination	Rx (lb)	Ry (lb)*	RMz (lb*ft)
1.0*Dead	0	7 345	0
1.0*Dead + 1.0*Snow	0	79 660	0
1.0*Dead + 1.0*Wind P1	47 674	- 4 832	123 732
1.0*Dead + 1.0*Wind P2	21 373	-129 100	51 574

* Ry negative is an uplift force.

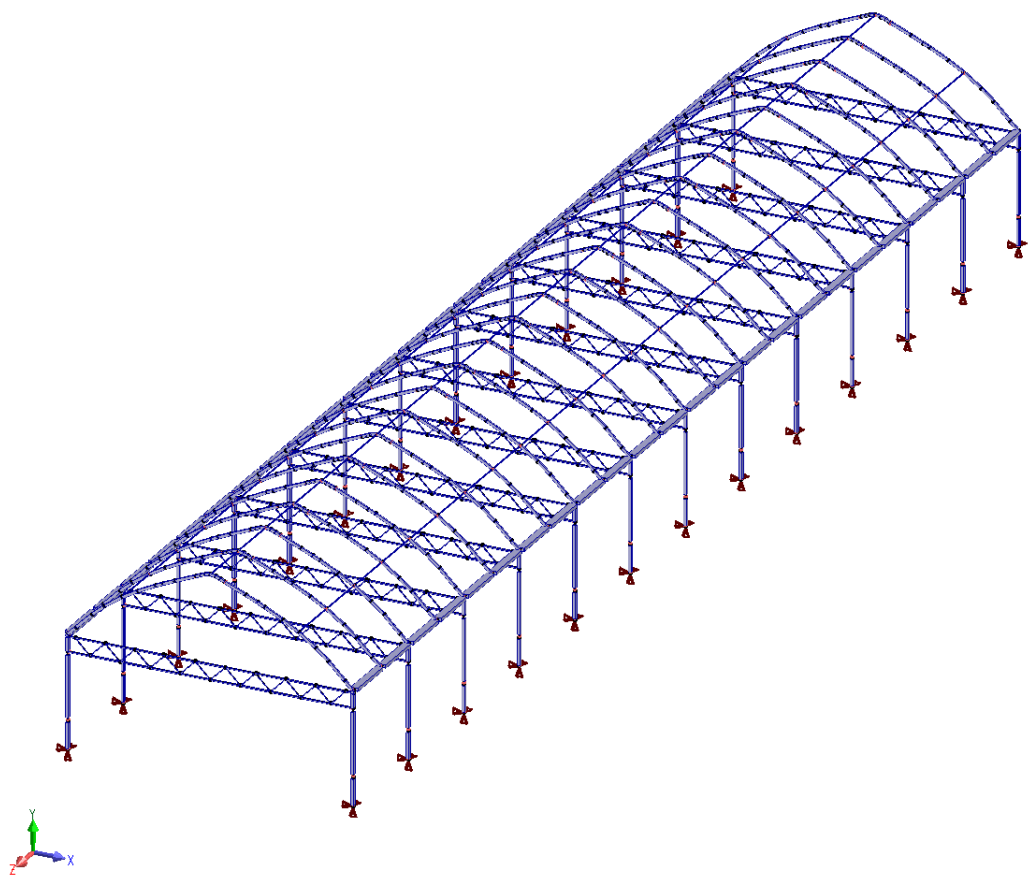


Figure 2 : Greenhouse Overview

The table 2 belows shows maximum individual **non-factored** reactions forces take on center typical axis:

Table 2: Individual maximum reaction forces non-factored

No joint	Combination	Rx (lb)	Ry (lb)	RmZ (lb*ft)
1	1.0D	0	295	0
1	1.0D + 1.0S	0	3 187	0
1	1.0D + 1.0WP1	-2 725	-739	5 913
1	1.0D + 1.0WP2	-523	-5 461	1 512
2	1.0D	0	295	0
2	1.0D + 1.0S	0	3 187	0
2	1.0D + 1.0WP1	-852	283	3 278
2	1.0D + 1.0WP2	-1 094	-4 864	2 359

- Rx can be positive or negative depending the wind direction.
- Ry negative is an uplift force.
- D- Dead Load
- S- Snow Load
- WP1- Wind P1 is when the internal pressure is negative.
- WP2- Wind P2 is when the internal pressure is positive (parachute wind).

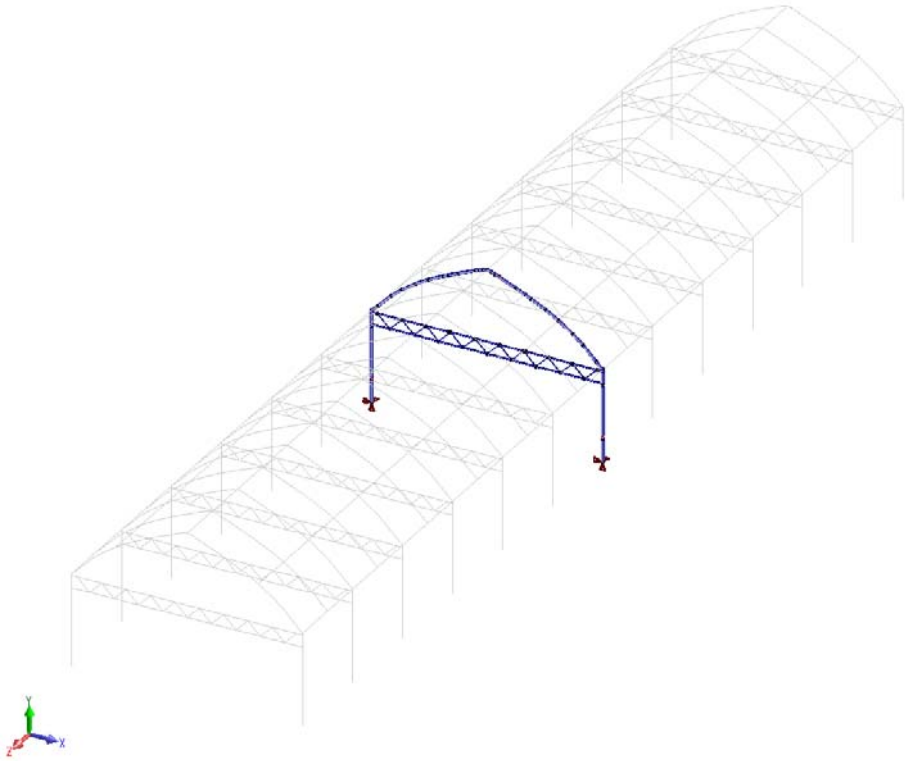


Figure 3 : Typical Center Axis ID



The table 3 belows shows maximum individual **factored** reactions forces take on center typical axis:

Table 3: Individual maximum reaction forces factored

No joint	Combination	Rx (lb)	Ry (lb)	RmZ (lb*ft)
1	1.4D	0	413	0
1	1.2D + 1.6S	0	4 982	0
1	1.2D + 1.0WP1	-2 724	-680	5 911
1	1.2D + 1.0WP2	-522	-5 402	1 511
2	1.4D	0	413	0
2	1.2D + 1.6S	0	4 982	0
2	1.2D + 1.0WP1	-852	342	3 280
2	1.2D + 1.0WP2	-1 095	-4 805	2 360

- Rx can be positive or negative depending the wind direction.
- Ry negative is an uplift force.
- D- Dead Load
- S- Snow Load
- WP1- Wind P1 is when the internal pressure is negative.
- WP2- Wind P2 is when the internal pressure is positive (parachute wind).

*** Please note that with the method of calculation for **wind load** in accordance with ASCE 7-10, the difference between the non-factored and factored reactions forces are low. The ASCE 7-10 method already factored the Wind Speed in accordance with the building risk category. The soil bearing capacity must be factored accordingly.*



4- Conclusion

Harnois Greenhouses is a division of Industries Harnois Inc, a Canadian manufacturer of steel structures to develop and manufacture greenhouse that contribute to the goals achievement of our customers. Every greenhouse family is modeled with 3D structural software and mechanically tested for modeling validation.

The Luminosa S9 (1) x 30' x 144' @ 12' under gutter was designed to support climatic conditions required by the IBC 2015 for the town of Puyallup, WA:

Snow load = 30 psf, ground snow load, heated greenhouse
Wind speed = 110 MPH, 3 sec gust, ASCE 7-10, Cat 1, Exp. B, Partially Encl.

Here is the summary of the maximum column reaction:

Non-factored	Factored
2 725 pounds in lateral force (Rx)	2 724 pounds in lateral force (Rx)
3 187 pounds in compression (Ry+)	4 982 pounds in compression (Ry+)
-5 461 pounds in uplift (Ry-)	-5 402 pounds in uplift (Ry-)
5 913 pounds*foot in moment (RmZ)	5 911 pounds*foot in moment (RmZ)

Please contact me, should you have any questions or if you need additional information.

Best regards.

LES INDUSTRIES HARNOIS INC.

Carl Savard, P. Eng.
Engineering Manager
LES INDUSTRIES HARNOIS INC.



5- References

Table 7-2 Exposure Factor, C_e

Terrain Category	Exposure of Roof ^a		
	Fully Exposed	Partially Exposed	Sheltered
B (see Section 26.7)	0.9	1.0	1.2
C (see Section 26.7)	0.9	1.0	1.1
D (see Section 26.7)	0.8	0.9	1.0
Above the treeline in windswept mountainous areas.	0.7	0.8	N/A
In Alaska, in areas where trees do not exist within a 2-mile (3-km) radius of the site.	0.7	0.8	N/A

The terrain category and roof exposure condition chosen shall be representative of the anticipated conditions during the life of the structure. An exposure factor shall be determined for each roof of a structure.

^aDefinitions: Partially Exposed: All roofs except as indicated in the following text. Fully Exposed: Roofs exposed on all sides with no shelter^b afforded by terrain, higher structures, or trees. Roofs that contain several large pieces of mechanical equipment, parapets that extend above the height of the balanced snow load (h_b), or other obstructions are not in this category. Sheltered: Roofs located tight in among conifers that qualify as obstructions.

^bObstructions within a distance of $10h_o$ provide "shelter," where h_o is the height of the obstruction above the roof level. If the only obstructions are a few deciduous trees that are leafless in winter, the "fully exposed" category shall be used. Note that these are heights above the roof. Heights used to establish the Exposure Category in Section 26.7 are heights above the ground.

Table 7-3 Thermal Factor, C_t

Thermal Condition ^a	C_t
All structures except as indicated below <i>Partially heated (effet de serre)</i>	1.0
Structures kept just above freezing and others with cold, ventilated roofs in which the thermal resistance (R-value) between the ventilated space and the heated space exceeds $25 \text{ }^\circ\text{F} \times h \times \text{ft}^2/\text{Btu}$ ($4.4 \text{ K} \times \text{m}^2/\text{W}$).	1.1
Unheated and open air structures	1.2
Structures intentionally kept below freezing	1.3
Continuously heated greenhouses ^b with a roof having a thermal resistance (R-value) less than $2.0 \text{ }^\circ\text{F} \times h \times \text{ft}^2/\text{Btu}$ ($0.4 \text{ K} \times \text{m}^2/\text{W}$)	0.85

^aThese conditions shall be representative of the anticipated conditions during winters for the life of the structure.

^bGreenhouses with a constantly maintained interior temperature of $50 \text{ }^\circ\text{F}$ ($10 \text{ }^\circ\text{C}$) or more at any point 3 ft above the floor level during winters and having either a maintenance attendant on duty at all times or a temperature alarm system to provide warning in the event of a heating failure.

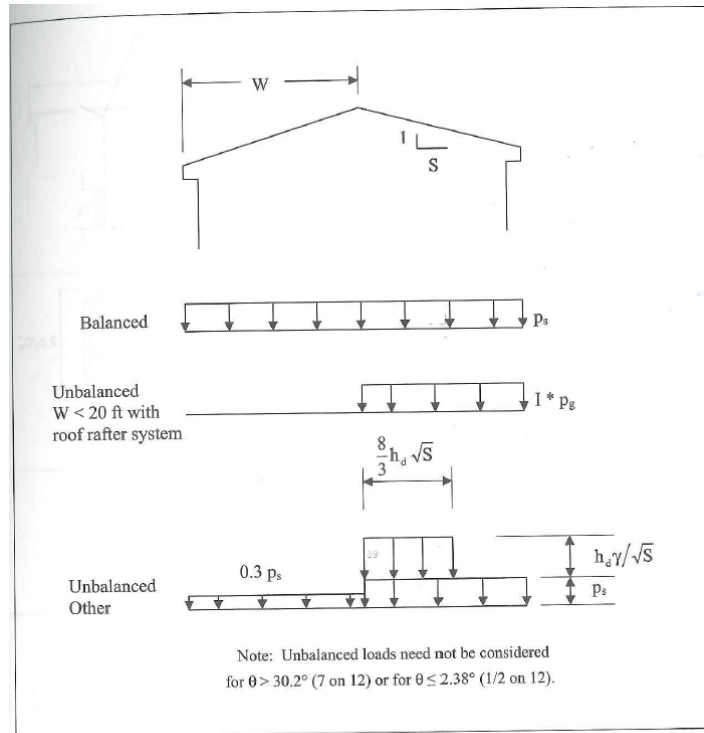
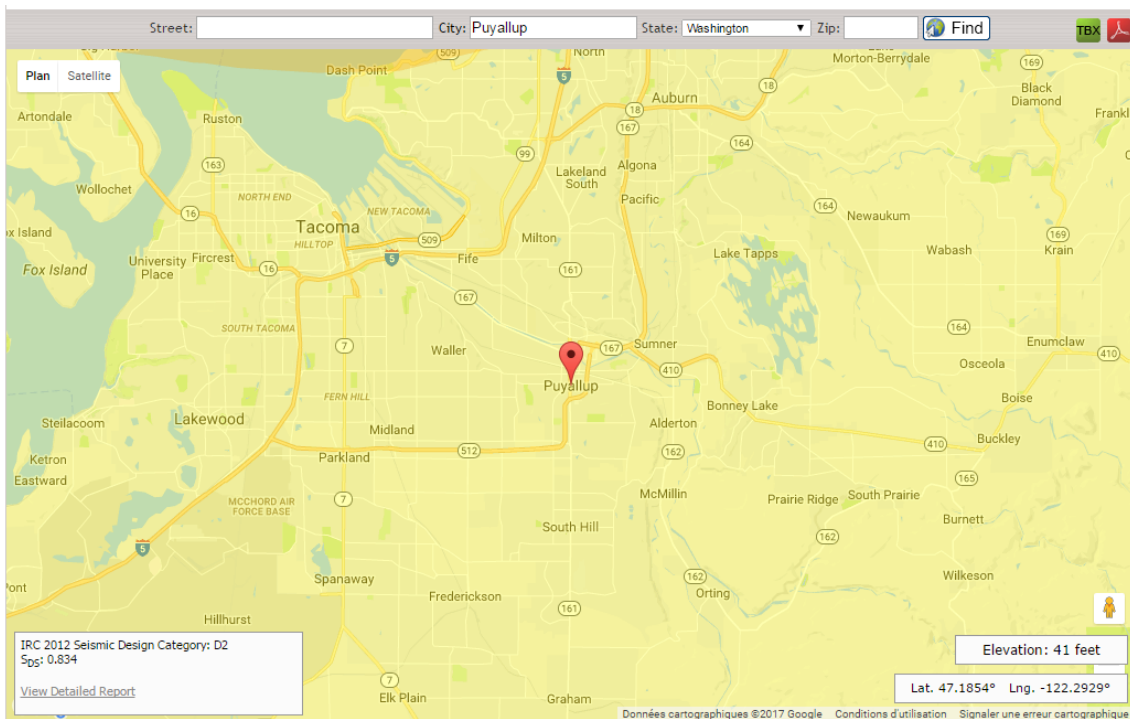


FIGURE 7-5 Balanced and Unbalanced Snow Loads for Hip and Gable Roofs.



Chapter 2

COMBINATIONS OF LOADS

2.1 GENERAL

Buildings and other structures shall be designed using the provisions of either Section 2.3 or 2.4. Where elements of a structure are designed by a particular material standard or specification, they shall be designed exclusively by either Section 2.3 or 2.4.

2.2 SYMBOLS

A_h = load or load effect arising from extra ordinary event A
 D = dead load
 D_i = weight of ice
 E = earthquake load
 F = load due to fluids with well-defined pressures and maximum heights
 F_a = flood load
 H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
 L = live load
 L_r = roof live load
 R = rain load
 S = snow load
 T = self-straining load
 W = wind load
 W_i = wind-on-ice determined in accordance with Chapter 10

2.3 COMBINING FACTORED LOADS USING STRENGTH DESIGN

2.3.1 Applicability

The load combinations and load factors given in Section 2.3.2 shall be used only in those cases in which they are specifically authorized by the applicable material design standard.

2.3.2 Basic Combinations

Structures, components, and foundations shall be designed so that their design strength equals or exceeds the effects of the factored loads in the following combinations:

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
4. $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$

5. $1.2D + 1.0E + L + 0.2S$
6. $0.9D + 1.0W$
7. $0.9D + 1.0E$

EXCEPTIONS:

1. The load factor on L in combinations 3, 4, and 5 is permitted to equal 0.5 for all occupancies in which L_o in Table 4-1 is less than or equal to 100 psf, with the exception of garages or areas occupied as places of public assembly.
2. In combinations 2, 4, and 5, the companion load S shall be taken as either the flat roof snow load (p_f) or the sloped roof snow load (p_s).

Where fluid loads F are present, they shall be included with the same load factor as dead load D in combinations 1 through 5 and 7.

Where loads H are present, they shall be included as follows:

1. where the effect of H adds to the primary variable load effect, include H with a load factor of 1.6;
2. where the effect of H resists the primary variable load effect, include H with a load factor of 0.9 where the load is permanent or a load factor of 0 for all other conditions.

Effects of one or more loads not acting shall be investigated. The most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be considered to act simultaneously. Refer to Section 12.4 for specific definition of the earthquake load effect E .¹

Each relevant strength limit state shall be investigated.

2.3.3 Load Combinations Including Flood Load

When a structure is located in a flood zone (Section 5.3.1), the following load combinations shall be considered in addition to the basic combinations in Section 2.3.2:

1. In V-Zones or Coastal A-Zones, $1.0W$ in combinations 4 and 6 shall be replaced by $1.0W + 2.0F_a$.
2. In noncoastal A-Zones, $1.0W$ in combinations 4 and 6 shall be replaced by $0.5W + 1.0F_a$.

¹The same E from Section 12.4 is used for both Sections 2.3.2 and 2.4.1. Refer to the Chapter 11 Commentary for the Seismic Provisions.