CANADA PLAN SERVICE TRUSS DESIGN
by
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To review the analysis used to design CPS Roof Trusses, consider plan C-42, 40' span truss, 33 psf roof load at 4' oc spacing, #1 grade spruce lumber.

Analysis

Plan C-42 is a double-sloped single-W roof truss.

In developing the configurations of the members of the truss, we assumed the following: the web members would be joined to the bottom chord of the truss at the bottom chord one-third points; the angle between the exterior web member and the bottom chord would be 60°; the interior web member would run from the bottom chord one-third point to the ridge. The above assumptions differ slightly for double-W and triple-W double-sloped trusses and for single-sloped trusses.

With the above configuration, the truss axial forces are determined with the uniformly distributed load (udl) over the whole truss. The udl is resolved into concentrated loads applied at the joints in the top chord, and the forces in the members are determined by assuming that all joints are pinned. Below is the computer printout of the above analysis.

C-42

40 FT SPAN TRUSS 48 IN OC SPACING 33 PSF ROOF LOAD 4/12 ROOF SLOPE

MEMBER	LENGTH(FT)	SIZE	FORCE(LB)	MOMENT(LB-IN)	M/SF+P/AC	BRACES
A(1)	11.786	2 X 8	-6014.7	13753	.99	0
A(2)	13.333	2 X 6	5706.1	0	.583	0
A(3)	3.991	2 X 4	-1278.2	0	.261	0
A(4)	9.296	2 X 8	-5341.1	13753	.947	0
A(5)	9.105	2 X 4	1565.5	0	.419	0
A(6)	13.333	2 X 6	3960	0	.405	0

	REACTION AT HEEL	FORCE AT HEEL	OTHER JOINTS
EXTERNAL FORCES	2640	738	1320 1164

LUMBER-2X6 AND GREATER- NO 1 GRADE SPRUCE
-2X4-NO 2 OR CONSTRUCTION GRADE SPRUCE

LOADINGS FOR DIFFERENT TRUSS SPACING

TRUSS SPACING(IN)	96	48	32	24	16	12
LOADING(PSF)	15	33	50	66	99	132
LENGTH OF TOP CHORD(FT)	22	23	24	25		
OVERHANG(FT)	.68	1.629	2.577	3.526		

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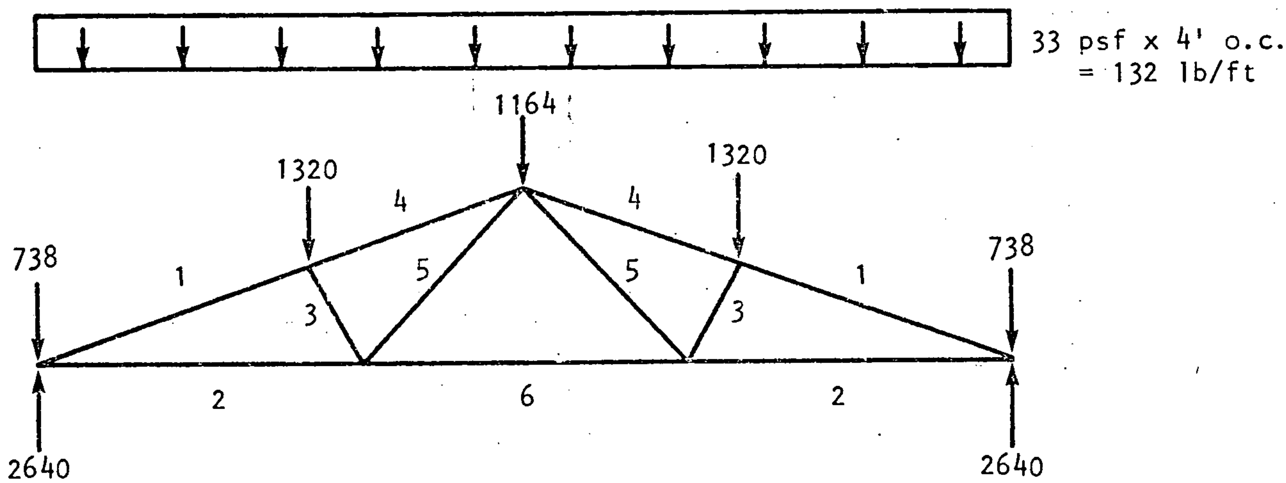
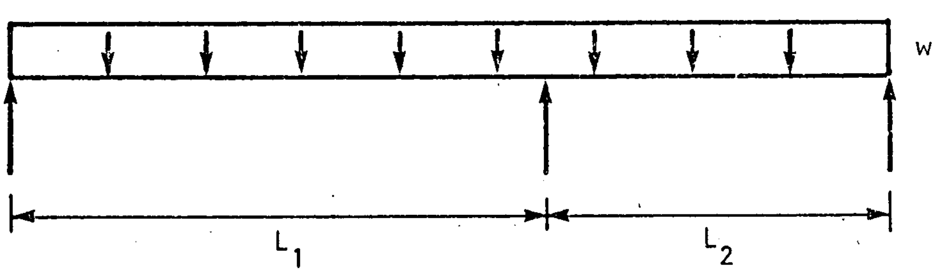
In the computer printout, the truss members are identified as indicated in the diagram below.



A lot of other information is included in the printout. The web member lengths indicated are the actual lengths of lumber required to build the truss, not the lengths used in the analysis which are from the underside of the top chord to the underside of the bottom chord.

Also included in the printout is a value for moment in the top chord. In the single-W truss above, members 1 and 4 are not equal in length. In the analysis of the double-W and triple-W trusses, the top chord is divided by joints into sections of equal length. For moments in the latter, the beam diagrams on pages 2-132 and 2-133 of the AISC Manual of Steel Construction, sixth edition were used. We used the continuous beam with three equal spans for the double-W and the continuous beam with four equal spans for the triple-W, which resulted in maximum moments of $0.1167\ w\ l^2$ and $0.1205\ w\ l^2$, respectively.

The determination of the moment for the single-W is quite a bit more complicated. In this case the top chord is a continuous beam with two unequal spans. To determine the moment in this case, the slope-deflection method of indeterminate structural analysis for continuous beams was used. The loading giving the maximum moment is shown below:



The maximum moment occurs at the center support and is as follows:

$$M_{max} = w\,L_1^{\,2} + 0.25EI\theta/L_1$$

Where $\theta = L_1L_2w\,(L_2^{\,2} - L_1^{\,2}) \;/\; ((L_1 + L_2) \times 0.25\,EI)$

= angle of rotation of beam about center support, radians

M_{max} = max moment, lb-in.

L_1, L_2 = lengths in ft.

w = udl in lb/ft.

E = modulous of elasticity, psi

I = moment of inertia, in ^{4}.

The moments in the computer printout for the single-W trusses could be reduced slightly. We should have multiplied the udl in the above equation by 0.949 (cos 18.4^o) to account for the roof slope.

The above assumptions that were made for determination of the axial forces and moments are to simplify the analysis. Actually, the truss joints are not pinned but semi-rigid. The degree of rigidity varies, with the heel joint probably the most rigid.

Hence, the method of analysis is not exact, although it does give a good approximation.

Gusset Design

Gusset size is controlled by two factors. The first factor is whether the gusset has enough surface area for the number of nails required. The second factor is whether the gusset has enough cross-sectional area to prevent failure in tension and shear through thickness.

The number of nails required in the heel joint, the bottom chord tensile splice joints and the web member tensile joints is the tensile force divided by the allowable load per nail. The number of nails required in the bottom chord portion of the joint with the web members is the greater of either the number required by the tensile web member or the number required by the difference in the tensile forces in the bottom chord members each side of the joint, divided by the allowable load per nail. For the compression web members, the number should be adequate to hold the joint together and resist a small tensile force if stress reversal occurs. Also it must have enough nails to resist the difference in the compressive forces in the top chord members on each side of the joint at the top chord. For the top chord splice joints, there must be enough nails to handle the shear in the top chord and some moment (if the joint cannot be placed at a point of inflection). The point of inflection usually occurs between L/5 and L/3 from the support points. The splice joint is located as close as possible to the L/4 point.

The top chord ridge joint gusset should have the same number of nails as required by the tensile web member in this gusset.

After the gussets are sized for nailing, they must be checked for shear and tension. Below are properties of ½" douglas fir plywood (5 ply) necessary for shear and tension stress checks:

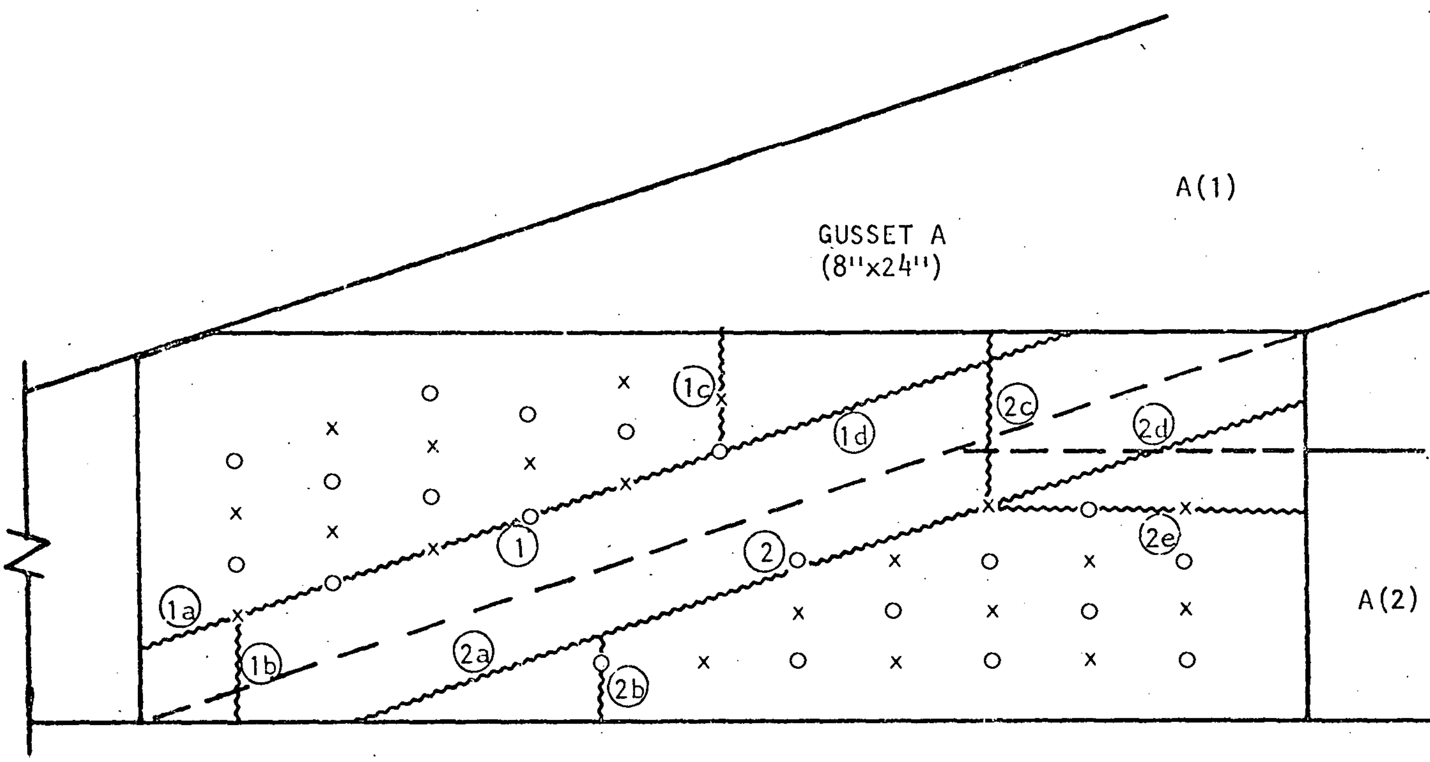
Allowable stresses:

	basic stress	x	load duration	x	low human occupancy	=	modified stress
tension ∥ to face grain =	1875	x	1.15	x	1.25	=	2695 psi
shear through thickness							
∥ or ⊥ to face grain =	210	x	1.15	x	1.25	=	302 psi
$\pm 45^{\circ}$ to face grain =	425	x	1.15	x	1.25	=	11 psi
$\pm 18.4^{\circ}$ to face grain =	298*	x	1.15	x	1.25	=	428 psi

Thickness of plies:

∥ to face grain = 0.297 (tension)
⊥ to face grain = 0.198
∥ + ⊥ to face grain = 0.495 (shear)

Below is gusset A of C-42 with nailing pattern and possible plywood failure lines:



*basic stress = $210 + 18.4^{\circ}/45^{\circ} \times (425-210) = 298$ psi.

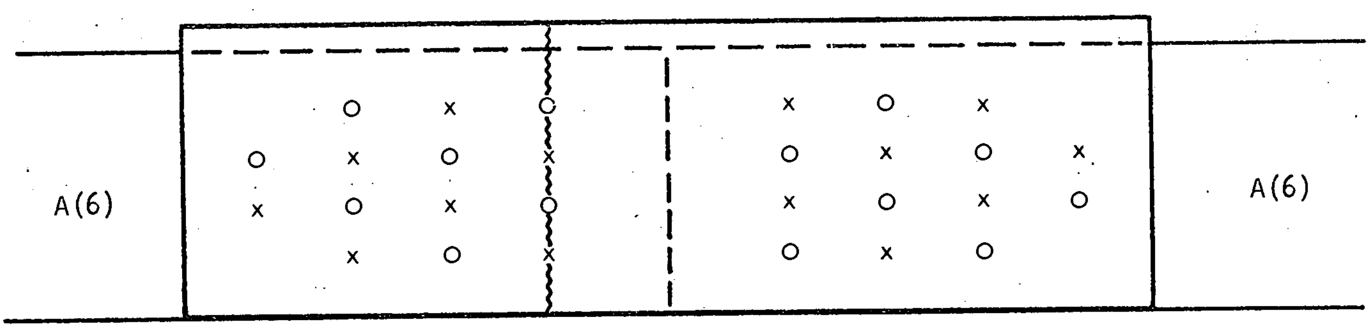
Route	*Nail Effect	Length	x	Plywood Thickness	x	Allowable Stress (psi)	=	Allowable Force (lb)	Critical Force (lb)
1a		2"	x	0.495"	x	428	=	424	424
1b		2"	x	0.297"	x	2695	=	1600	
1		10.5"	x	0.495"	x	428	=	2225	2225
1c	*(-0.6x1x0.1 +	2.5"	x	0.297")	x	2695	=	1839	
1d		8"	x	0.495	x	428	=	1695	1695
						Max. force/gusset path 1	=		4344 lb.
2a		4"	x	0.495	x	428	=	847	847
2b		1.25"	x	0.297	x	2695	=	1000	
2		8.5"	x	0.495	x	428	=	1801	1801
2c		3.5"	x	0.297"	x	2695	=	2801	
2d		7"	x	0.495	x	428	=	1483	
2e		6.5"	x	0.495	x	302	=	972	972
						Max. force/gusset path 2	=		3620 lb.

Since path 2 is critical and there are 2 gussets per joint, the max. force that joint A can handle with the 8" x 24" gussets is 2 x 3620 = 7240 lb. Since the force in A (1) is only 6014 lb., gusset A at 8" x 24" is satisfactory.

Below is a check for failure of gusset C:

*Nail Effect	Length	x	Plywood Thickness	x	Allowable Stress (psi)	=	Allowable Force (lb)
*(-0.6x1x0.1 +	6"	x	0.297")	x	2695	=	4156 lb

There is only one path that is critical in gusset C. The max. allowable force in 6" deep gusset C is 2 x 4156 = 8312 lb. The max. force in A(6) is 3960 lb. therefore at 6" x 19" gusset C is satisfactory.



GUSSET C (6"x19")

*From The Effect of Nailing Patterns on the Tensile Strength of Plywood Gussets, Turnbull, J.E. and Todd, D.M., Canadian Agricultural Engineering, Vol. 12, No. 1, May, 1976.

Lumber Types

The plans show truss designs of douglas fir (species group A) or spruce (species group D) sawn lumber.

Lumber Grades

For 2" x 4" members, the truss plans specify the use of #2 grade or construction grade lumber. The allowable stresses for this lumber size (light framing sizes - thickness 2 to 4 inches and width 2 to 4 inches), are given in the Code of Recommended Practice for Engineering Design in Timber, CSA Standard 086.

For 2 x 6 and larger members, the truss plans specify the use of #1 grade or #2 grade lumber. The allowable stresses for these lumber sizes (joist and plank sizes - tickness 2 to 4 inches and width 6 inches or more) are given in the Code of Recommended Practice for Engineering Design in Timber, CSA Standard 086.

Lumber Sizes

The maximum lumber size that the plans specify is 2" x 10" because larger sizes are not readily available in all parts of Canada and special lateral bracing is required for compression members larger than 2" x 10".

For 2" x 12" top chord members, lateral braces at 8' o.c. should be provided for the underside with the nailing girts on the top edge to satisfy the section on Lateral Support of Bending Members, CSA Standard 086.

There is no limitation on the size of the bottom chord for lateral bracing.

The plans specify 2 x 4 web members. In the longer compression web members lateral bracing has been specified to satisfy the requirements of CSA Standard 086 on Compression Members.

Lumber Dimensions

The Actual and Nominal Dimensions used to determine the sectional properties of the sawn lumber (dry) specified in the truss plans are listed in the table in Appendix G, Code of Recommended Practice for Engineering Design in Timber, CSA Standard 086.

Stress Modification Factors

The allowable stresses mentioned above can be increased for certain types of loadings and for certain types of farm buildings.

For a load duration of 2-months (snow), the allowable stresses can be increased by a factor of 1.15.

For a low human occupancy farm building as defined by the Canadian Farm Building Code, the allowable stresses can be increased by a further factor of 1.25.

For low human occupancy farm buildings in which the framing elements are spaced at 48" o.c., or less, the allowable stresses can be increased by a further factor of 1.10. The definition for "load sharing system" is in the Canadian Farm Building Code. The 10% increase is indicated in the Code of Recommended Practice for Engineering Design in Timber, CSA Standard 086.

Plywood Gussets

The gussets are designed to satisfy the allowable stresses for douglas fir plywood listed in CSA Standard 086. The low human occupancy and load duration stress modification factors were applied but the load sharing factor was not.

Truss Gusset Nails

The nail specified in the plans is the 6 gage "Truss Gusset" nail by the Steel Company of Canada. An allowable load of 296 lb and 369 lb per nail for spruce and douglas fir members respectively in double shear is permitted.

The minimum nail spacings specified for loads parallel to the grain of the sawn lumber are as follows:

	Spruce	Douglas Fir
end distance	2½"	3 "
edge distance	1¼"	1¼"
spacing perpendicular to grain	1 "	1"
spacing parallel to grain	2 "	2½"

The minimum edge distance specified for the plywood nailing is 1".

Trusses in High Human Occupancy

In this application, the stress modification factors and the allowable nail loads in general must be reduced.

The 2-month load duration factor of 1.15 remains unchanged. The low human occupancy farm building factor of 1.25 must not be applied. The load sharing factor of 1.10 can only be applied when the framing elements are spaced at 24" o.c. or less, not 48" o.c. or less as in low human occupancy farm buildings.

The allowable load per nail must be decreased to 237 and 296 lb for spruce and douglas fir members respectively.

In order to use the CPS trusses in high human occupancy buildings the total loads listed for trusses must be multiplied by the following factors:

Truss spacing	96"	48"	32"	24"
factor	0.80	0.70	0.70	0.70