5. JOINT DESIGN PROCEDURES

5.1 General

The design requirements for truss plate joints, utilizing light gauge metal plates, shall be in accordance with CSA-086.1 Section 10.

1) These procedures do not apply to the following conditions:

   (a) corrosive conditions

   (b) galvanized truss plates used in lumber that has been treated with fire retardant and is used in wet service conditions or in locations prone to condensation

   NOTE:
   For metal connector plates used in environmental conditions that fall within the scope of (a) & (b) above, refer to Appendix E.

2) Design criteria for truss plates are based on the following conditions:

   (a) the plate is prevented from deforming during installation;

   (b) the teeth are normal to the surface of the lumber;

   (c) the tooth penetration in joints is not less than that used in the tests to determine the resistance values; and

   (d) the lumber beneath the plate does not contain wane, loose knots, or knot holes

3) Thickness of members used in joints shall not be less than twice the tooth penetration.

4) Joint design shall be based on tight fitted joints with truss plates placed on opposing faces in such a way that, at each joint, the plates on opposing faces are identical and are placed directly opposite each other.

5) The lateral resistance value used to determine necessary plate area for any member shall be the appropriate value considering direction of load relative to grain and direction of load relative to primary axis of plate (see fig. 5.1.(5)). The resistance value is determined using the test values in conjunction with the formulae contained in Clause 5.3.3.

6) The unit values of lateral resistance of teeth shall be expressed as per tooth, per rosette, or per net area, whichever is appropriate or preferred. The design shall be based on net area method using test values or on gross area method using 80 percent of the test values and with areas defined in items (a) and (b) as follows:

   (a) the gross area is defined as the total area of member covered by a truss plate:

   (b) the net area is defined as the total area of a member covered by a truss plate less the area within a given distance from the edge or end of member. For net area calculation, the minimum end distance measured parallel to grain, shall be the greater of 12 mm (1/2”), or 1/2 the length of tooth; the minimum edge distance measured perpendicular to grain, shall be the greater of 6 mm (1/4”), or 1/4 the length of the tooth.

   Any joint in a truss may be designed by either net or gross area method of joint design but not a combination of both within same joint.

7) Minimum Bite for Chords and Webs

   At all joints, the connector plates are to be sized such that the minimum bites into all chords and webs are as given in Table 5.1.(7):

Table 5.1.(7) Minimum Bite For Chords and Webs, mm (in)

Truss Length L, m (ft)				
Lumber Size	0 < L ≤ 12.5 (0 < L ≤ 41)	12.5 < L ≤ 18.3 (41 < L ≤ 60)	18.3 < L ≤ 24.4 (60 < L ≤ 80)	24.4 < L ≤ 30.5 (80 < L ≤100)
38x64 (2x3)	38 (1.5)	45 (1.75)	n/a	n/a
38x89 (2x4)	38 (1.5)	45 (1.75)	51 (2.0)	57 (2.25)
38x114 (2x5)	38 (1.5)	45 (1.75)	51 (2.0)	57 (2.25)
38x140 (2x6)	38 (1.5)	51 (2.0)	57 (2.25)	64 (2.5)
38x184 (2x8)	51 (2.0)	57 (2.25)	64 (2.5)	76 (3.0)
38x235 (2x10)	64 (2.5)	70 (2.75)	76 (3.0)	83 (3.25)
38x286 (2x12)	76 (3.0)	76 (3.0)	83 (3.25)	89 (3.5)

Note: (1) Plates must be sized so that the min. bite into chords is as shown above:
- (a) parallel to chord direction
- (b) perpendicular to chord direction

(2) Plates must be sized so that the min. bite into webs is as shown above:
- (a) parallel to chord direction
- (b) perpendicular to chord direction
- (c) along the centreline of the web

8) Measurement and display of plate offsets shall be in 6 mm (1/4") increments, unless the plate placement can be otherwise described uniquely.

5.2 Connector Plate Evaluation

1) The metal connector plate design values (per tooth, nail, square mm, linear mm, or other unit) shall be determined in accordance to procedures contained in CSA-S347 "Method of Test for Evaluation of Truss Plates used in Lumber Joints" latest edition.

2) The tensile and shear values, for connector plates manufactured from a grade of steel higher than that used in the plate testing program, may be adjusted by the ratio of the ultimate tensile strength of the steel used in the manufacturing of the plate to that of the steel used in the test plates. This adjustment does not apply to the gripping values; these values may require adjustment , so should be verified by test.

3) Strength resistance values for plates and teeth are to be obtained from tests carried out in accordance with CSA Standard S347, where the resistance values are
- (a) the average, divided by 1.6, of the 3 lowest of 10 ultimate test values for lateral resistance of the teeth;
- (b) the average of the 2 lowest of 3 corrected test values for tensile strength of the plate; and
- (c) the average of the 2 lowest of 3 corrected test values for shear strength of the plate at the angles specified;

4) Lateral slip resistance values are to be obtained from tests carried out in accordance with CSA Standard S347, where the resistance values are the average of 10 test loads at 0.8 mm wood-to-wood slip divided by 1.4.

5.3 Strength Limit States

5.3.1 General

Truss plate joints shall be designed such that for the strength limit state, the effect of factored load is less than or equal to;

(a) the factored ultimate lateral resistance of the teeth;
(b) the factored tensile resistance of the plates; and
(c) the factored shear resistance of the plates;

5.3.2 Modification Factors

1) Load Duration Factor, K_D

The load duration factor K_D for truss plates is as previously given in Table 4.3.4.(1)

2) Service Condition Factor, K_{SF}

The service condition factor, K_{SF} , for truss plates is given in Table 5.3.2.(2)

Table 5.3.2.(2) Service Condition Factor, K_{SF}

LUMBER CONDITION AT TIME OF MANUFACTURE			
Seasoned (Moisture Content 15%)		Unseasoned (Moisture Content > 15%)	
LUMBER CONDITION IN SERVICE			
DRY	WET	DRY	WET
1.00	0.67	0.80	0.67

3) Treatment Factor, K_T

The fire-retardment treatment factor, K_T, for truss plates is given in Table 5.3.2.(3)

Table 5.3.2.(3) Fire Retardant Treatment Factor, K_T

Not Seasoned after Treatment	Seasoned after Treatment
0.80	0.90

5.3.3 Ultimate Lateral Resistance

The ultimate lateral resistance of the teeth,n_u, are calculated as follows:

(a) For loads parallel to the primary axis of the plate

$$n_u = \frac{p_u q_u}{p_u \sin^2 \theta + q_u \cos^2 \theta}$$

and

(b) For loads perpendicular to the primary axis of the plate

$$n'_u = \frac{p'_u q'_u}{p'_u \sin^2 q + q'_u \cos^2 q}$$

where p_u, q_u, p'_u, q'_u are the ultimate lateral resistances obtained in accordance with Clause 5.2.(3) (a) used with the following values of θ and ρ :

p_u : $\theta = 0^0, \rho = 0^0$

q_u : $\theta = 90^0, \rho = 0^0$

p'_u : $\theta = 0^0, \rho = 90^0$

q'_u : $\theta = 90^0, \rho = 90^0$

where θ and ρ are defined in Figure 5.1(5)

When the primary axis of the plate is oriented at an angle other than parallel or perpendicular to the direction of the load, the resistance value shall be determined by linear interpolation between the values n_u and n'_u.

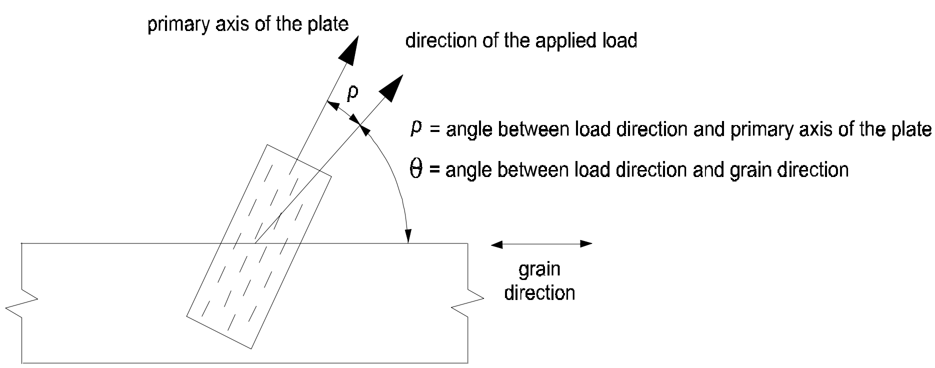

Figure 5.1.(5)
Truss Plate, Load and Grain Orientation

5.3.4 Tensile Resistance

Tensile resistance of the plate, t_p, is determinded for both parallel to and perpendicular to the direction of the plate primary axis in accordance with 5.2.(3) (b). For all other angles, tensile resistance shall be determined by linear interpolation.

5.3.5 Shear Resistance

Shear resistance of the plate, v_p, is determinded for specified angles of plate primary axis to load direction in accordance with 5.2.(3) (c). For all other angles, shear resistance shall be determined by linear interpolation.

5.3.6 Factored Resistance of Truss Plates

For the strength limit state the factored resistances of truss plates shall be determined as follows:

(a) The factored lateral resistance of the teeth, N_r , shall be expressed in terms of the surface area of the plates.

$$N_r = \phi N_u J_H$$

where $\phi = 0.9$

$N_u = n_u(K_D K_{SF} K_T)$

J_H = moment factor for heel connection (Clause 5.5.7.(1) or (2))

(b) The factored tensile resistance of the plates, T_r , shall be expressed in terms of the dimension of the plate measured perpendicular to the line of action of the applied forces.

$$T_r = \phi\, t_p$$

where $\phi = 0.6$

t_p = tensile resistance of the plate (Clause 5.3.4)

(c) The factored shear resistance of the plates, V_r , shall be expressed in terms of the dimension of the plate measured along the line of action of the shearing forces.

$$V_r = \phi\, v_p$$

where $\phi = 0.6$

v_p = shear resistance of the plate. (Clause 5.3.5)

5.4 Serviceability Limit States

Truss plate joints shall be designed such that for the serviceability limit state the effect of specified loads is less than or equal to the lateral slip resistance of the teeth.

1) Lateral Slip Resistance

The lateral slip resistance of the teeth, n_s, shall be calculated as follows:

(a) For loads parallel to the primary axis of the plate

$$n_s = \frac{p_s q_s}{p_s \sin^2 q + q_s \cos^2 q}$$

and

(b) For loads perpendicular to the primary axis of the plate

$$n'_s = \frac{p'_s q'_s}{p'_s \sin^2 q + q'_s \cos^2 q}$$

where p_s, q_s, p'_s, q'_s are the lateral slip resistances obtained in accordance with Clause 5.2.(4) used with the following values of θ and ρ:

p_s: $\theta = 0^0, \rho = 0^0$

q_s: $\theta = 90^0, \rho = 0^0$

p'_s: $\theta = 0^0, \rho = 90^0$

q'_s: $\theta = 90^0, \rho = 90^0$

where η and θ are defined in Figure 5.1.(5)

When the primary axis of the plate is oriented at an angle other than parallel or perpendicular to the direction of the load, the resistance value shall be determined by linear interpolation between the values n_s and n'_s.

2) For the serviceability limit state, the lateral slip resistance of the teeth, N_{rs}, shall be determined as follows:

$$N_{rs} = n_s K_{SF}$$

Where K_{SF} is the same as for strength limit state Table 5.3.2.(2)

5.5 Member Joint Connections

5.5.1 Connection of Tension Members

1) The factored lateral resistance, N_r, in each tension member must be a minimum of 100% of the factored axial load in the member.

2) There must be sufficient factored tensile resistance, T_r, in the connector plates to transmit the full factored axial load in each tension member, considering the appropriate planes of action.

5.5.2 Connection of Compression Members

1) Metal connector plates resisting factored compressive axial loads shall be sized to provide factored lateral resistance, N_r, equal to the vectorial sum of no less than 50% of the component factored loads normal to the wood member interface, and 100% of the component factored loads parallel to the wood member interface.

2) Truss plates shall not be considered to transfer compression loads at joints.

5.5.3 Connection of Members for Shear

1) There must be sufficient factored lateral resistance of the teeth, N_r, in webs and chords to transmit the factored shear loads at a joint.

2) There must be sufficient factored shear resistance, V_r, in the truss plates to transmit the factored shear loads at a joint.

5.5.4 Combined Shear-Tension Resistance

The combined factored shear and tension resistance, C_{ST}, of the metal connector plate in the contact area of webs and chords, shall be determined as follows:

$$C_{ST} = \left(ST_{L1}L_1 + ST_{L2}L_2\right)$$

where;

ST_{L1} - combined factored shear/tension resistance of the pair of metal connector plates through the line of contact L1. (see Figure 5.5.4)

L_1 - length of effective steel at the horizontal edge of the member under consideration.

ST_{L2} - combined factored shear/tension resistance of the pair of metal connector plates through line of contact L2.

L_2 - length of effective steel at the vertical edge of the member under consideration.

$$ST_{L1} = V_{rL1} + \left(\frac{\theta_1}{90}\right)\left(T_{rL1} - V_{rL1}\right)$$

$$ST_{L2} = T_{rL2} + \left(\frac{\theta_1}{90}\right)\left(V_{rL2} - T_{rL2}\right)$$

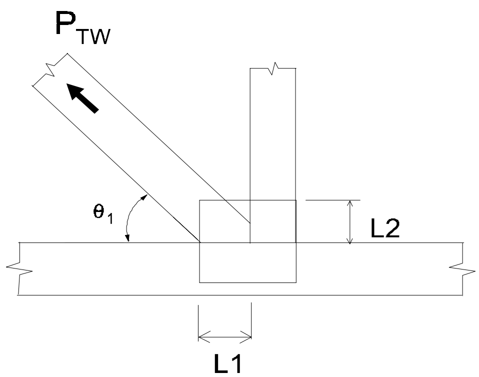

Figure 5.5.4
Shear-Tension Lengths and Angles

V_rL_1 - factored shear resistance parallel to the line of action, L1

V_rL_2 - factored shear resistance parallel to the line of action, L2

T_rL_1 - factored tensile resistance perpendicular to the line of action, L1

T_rL_2 - factored tensile resistance perpendicular to the line of action, L2

P_{TW} - factored tensile force in web

C_{ST} (L1 and L2 shown in figure 5.5.4) μ P_{TW}

NOTE: Where the truss plate extends significantly past any chord and/or web member, additional blocking is recommended.

5.5.5 Net Section Lumber Check (h')

At all joints, members shall have metal connector plates sized and/or positioned so that the axial stress index of the member is not exceeded on the reduced net section resulting from the coverage of the plate (See Figure 5.5.5)

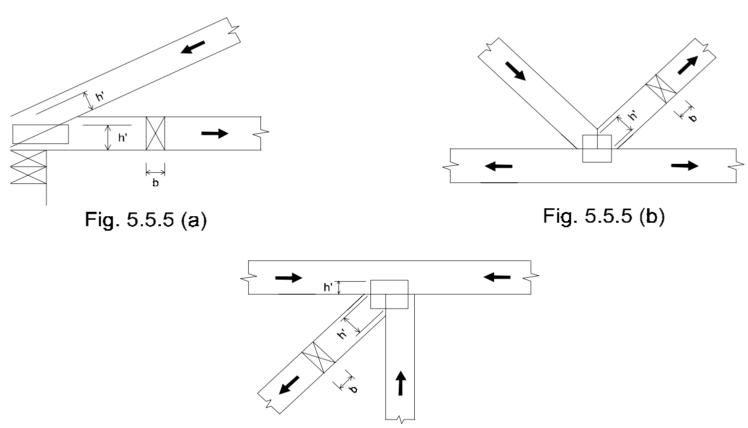

Fig. 5.5.5 (a)

Fig. 5.5.5 (b)

Fig. 5.5.5 (c)

Figure 5.5.5
Typical h' Dimensions

5.5.6 Tension Perpendicular-To-Grain Considerations

Any joint which carries a factored concentrated load that is perpendicular to the chord or has a component that is perdendicular to the chord and/or has a shear component that is perpendicular to the chord and exceeds 2.5 kN (562 lbs) must be reinforced for tension perpendicular-to-grain with a minimum chord bite as follows:

Min. Bite (mm) = $\frac{P - 2.500}{0.041}$ For Spruce-Pine-Fir

Min. Bite (mm) = $\frac{P - 2.500}{0.055}$ For Douglas-Fir-Larch

where P = Factored Concentrated Load, kN

The calculated minimum bite requirement need not exceed 3/4 of the depth of the lumber.

5.5.7 Heel Joint Considerations

1) To allow for moment effects at the heel joint of pitched trusses, the heel joint moment factor J_H shall be as given in Table 5.5.7.(1)

Table 5.5.7.(1) Heel Joint Moment Factors, J_H

Slope of top chord	J_H
Under 1/4 slope	0.85
1/4 to less than 1/3 slope	0.80
1/3 to less than 1/2.4 slope	0.75
1/2.4 to 1/2.2 inclusive	0.70
over 1/2.2 slope	0.65

2) In lieu of the values from the table above, the following formula can be used in determining the Heel Joint Moment Factor:

$$J_H = 0.85 - 0.05\,(12 \tan\theta - 2.0)$$

$$0.65 \leq J_H \leq 0.85$$

θ = the angle between the top and bottom chord

3) Where the vertical reaction results in factored shear loads that exceed the factored shear resistance of the lumber, the heel joint lumber may be reinforced by additional plating. For the design of the additional plating for girder type heels, refer to Appendix F.

4) The heel joint of a chord extended rafter shall be plated as an ordinary heel joint with the appropriate heel joint moment factor applied. Consideration should be given to prevent splitting due to tension perpendicular-to-grain and longitudinal shear by supplementary plating on the continuous rafter.

5.5.8 Chord Member Splice Considerations

5.5.8.1 General

For all chord splices the plate width shall be at least 65% of the width of the chord member.

5.5.8.2 Tension Splices

1) When determining the factored tensile resistance of the metal connector plate, the maximum extension of the metal connector plate for an unblocked chord splice is 13 mm (1/2”).
2) In the case of blocked tension splices, the total plate effectiveness shall be modified by the factor K as defined by the following equation:

$$K = 0.97e^{-0.001(3.937 + 0.0186(88.9-h))X}$$

where:

h = Actual width of wood member, mm.
X = Extension of plate above member. Maximum X allowed in this calculation is 89 mm (3.5”).

Note: (1) For an un-blocked tension splice with an extension of 13mm (1/2”) or less, K is equal to 1.00
(2) In the case of a splice occurring at the panel joint, webs framing into joint shall be considered as blocking.
(3) Maximum plate width to be applied with effectiveness factor K cannot be in excess of the member actual width h, plus the maximum extension, X.

5.5.8.3 Compression Splices

1) Compression splice plates shall be designed so that the factored ultimate lateral resistance in each member will be at least equal to 65% of the factored compressive axial load.
2) In plumb cut compression joints the metal connector plates resisting factored compressive axial loads shall be sized to provide factored ultimate lateral resistance, equal to the vectorial sum of no less than 65% of the component factored loads normal to the wood member interface and 100% of the component factored loads parallel to the wood member interface.

5.5.8.4 Moment Considerations

When in line members terminate at a splice,where chord moment should be considered, the splice plates must have sufficient resistance to transfer this factored bending moment in addition to the factored axial loads. This resistance is in both tooth gripping and plate steel section. See also clause 4.6.2

5.5.9 Compression Perpendicular-To-Grain

Any joint which carries a factored concentrated compressive load that subjects the member to compression perpendicular to grain stresses through the depth of the member (example: the bottom chord on a bottom chord bearing flat truss) such that a reduction of bearing strength as described in section 4.4.4.(2) applies, may be reinforced with connector plates so that the increased bearing strength of section 4.4.4.(1) may be used. This bearing reinforcement consists of applying connector plates at the joint of a size that permit coverage of the chord member to within 6 mm (¼") of the edge making contact with the bearing. When using this reinforcement to reduce bearing size, the web member contact on the opposite surface to the bearing, must be at least equal to that of the bearing. See figure 5.5.9.

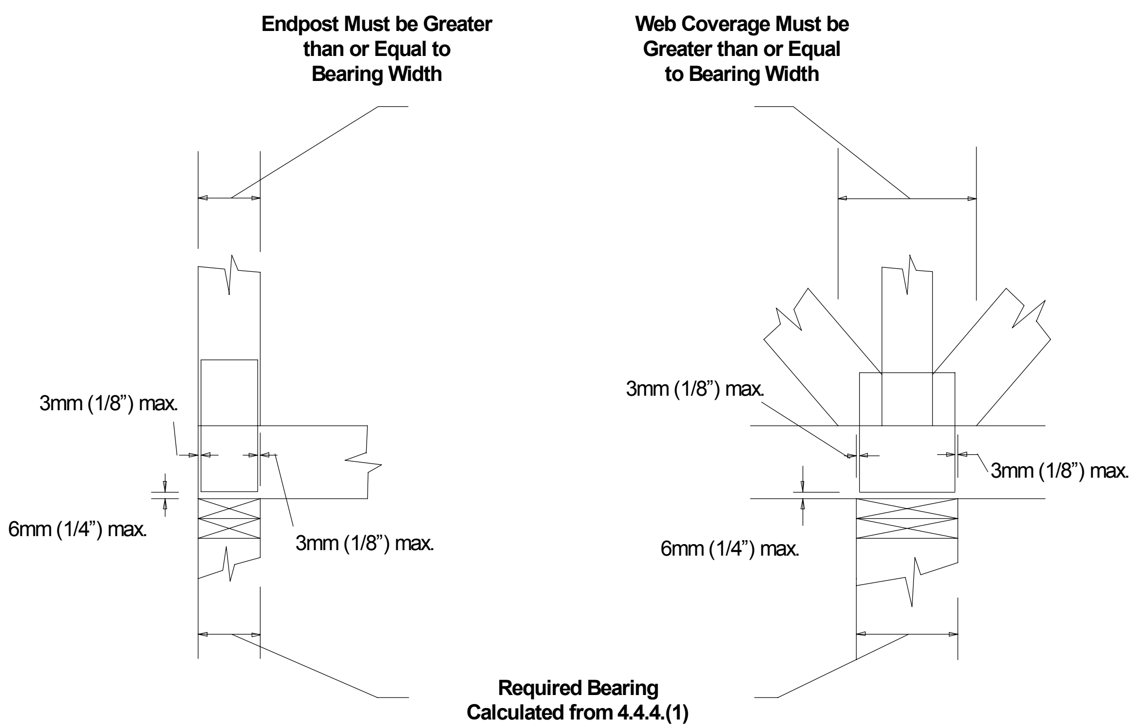

FIGURE 5.5.9 Bearing Reinforcement With Connector Plates