

FHWA Bridge Design Guidance No. 1

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Load Rating Evaluation of Gusset Plates in Truss Bridges

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Part – B Gusset Plate Resistance in Accordance with the Load Factor Rating Method (LFR)

Gusset connections of non-load-path-redundant steel truss bridges shall be evaluated during a bridge load rating analysis. Non-load-path-redundant bridges are those with no alternate load paths and whose failure of a main component is expected to result in the collapse of the bridge.

The evaluation of gusset connections shall include the evaluation of the connecting plates and fasteners. The capacity (referred to as the resistance in this Guidance) of a gusset connection is determined as the smaller resistance of the fasteners or gusset plates.

The following guidance is intended to provide for life safety and thus the resistance of the connection is required to be checked at maximum loads only. The maximum loads are the loadings specified in AASHTO Article 10.47. Owners may require that connections be checked for other loading levels such as overload to minimize serviceability concerns.

RESISTANCE OF FASTENERS:

For concentrically loaded bolted and riveted gusset connections, the maximum axial load in each connected member may be assumed to be distributed equally to all fasteners.

At maximum loads, the fasteners in bolted and riveted gusset connections shall be evaluated to prevent fastener shear and plate bearing failures. The provisions of AASHTO Article 10.56.1.3.2 shall apply for determining the resistance of fasteners to prevent fastener shear and plate bearing failures.

For unknown rivet types, the shear resistance of one rivet shall be taken as:

$$\phi R = \phi F m A_r \quad (1)$$

where:

ϕF = shear strength of one rivet. The values in Table 1 may be used for ϕF based on the year of construction:

Table 1

Year of Construction	ϕF ksi
Constructed prior to 1936 or of unknown origin	18
Constructed after 1936 but of unknown origin	21

m = the number of shear planes
 A_r = cross-sectional area of the rivet before driving

The shear resistance of a rivet in connections greater than 50.0 in. in length shall be taken as 0.80 times the value given in Eq. 1.

RESISTANCE OF GUSSET PLATES:

The resistance of a gusset plate shall be determined as the least resistance of the plate in shear, tension including block shear, compression, and combined flexural and axial loads.

GUSSET PLATES IN TENSION

Gusset plates subjected to axial tension shall be investigated for two conditions:

- Yield on the effective gross section, and
- Block shear rupture

The resistance for gusset plates in tension, R_r , shall be taken as the least of the values given by either yielding on the effective area or the block shear rupture resistance.

Effective Gross Section Yielding

$$R_r = A_e F_y \quad (2)$$

where:

A_e = effective gross cross-sectional area taking into account the possibility of net section fracture.

$$A_e = A_n + \beta A_g \leq A_g \quad (3)$$

A_n = net cross-sectional area of the plates as specified in AASHTO Article 10.16.14.

β = 0.0 for M 270 Grade 100/100W steels, or when holes exceed 1¼ inch in diameter.

= 0.15 for all other steels and when holes are less than or equal to 1¼ inch in diameter.

A_g = gross cross-sectional area of the plates.

F_y = minimum yield strength of the plates, as specified in AASHTO Table 10.2A.

For the determination of the gross and net section areas, the effective gross width of the gusset plate in tension may be determined by the Whitmore method. In this method, the effective width is measured across the last row of fasteners in the connection under consideration. The effective width is bound on either side by the closer of the nearest adjacent plate edges or lines constructed starting from the external fasteners within the first row and extending from these fasteners at an angle of 30 degrees with respect to the line of action of the axial force. Figures 1 and 2 provide examples for determining the effective width in tension in accordance with the Whitmore method.

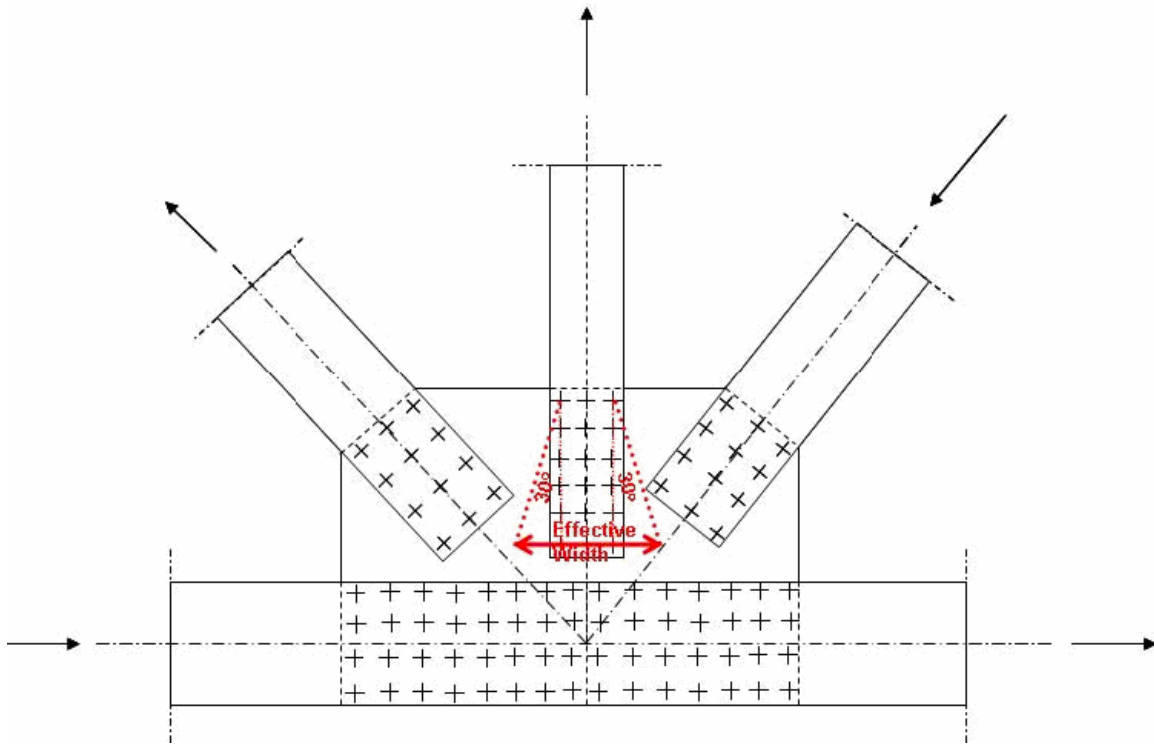


Figure 1 – Example 1 for using the Whitmore method to determine the effective width in tension

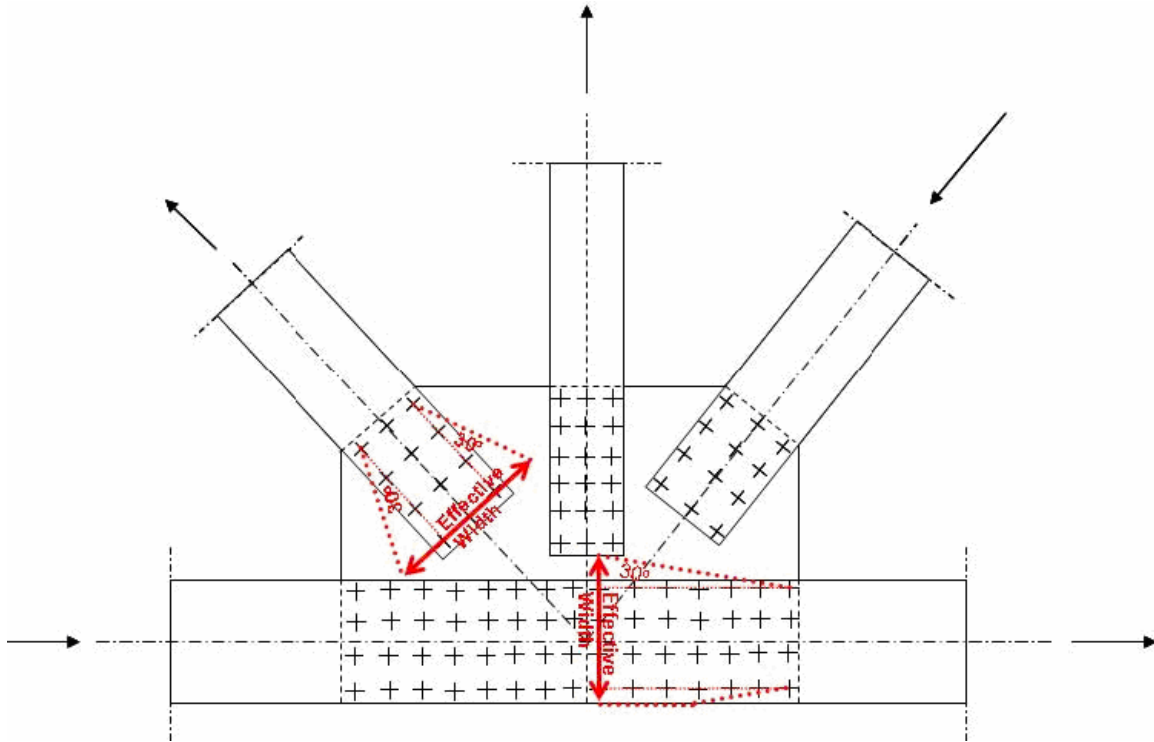


Figure 2 – Example 2 for using the Whitmore method to determine the effective width in tension

When using the Whitmore method, proximity of the connected members can affect the resistance of gusset plates in tension. Therefore, special attention must be exercised in congested areas to evaluate all possible failure modes of gusset connections.

Block Shear Rupture Resistance

The resistance to block shear rupture is that resulting from the combined resistance of parallel and perpendicular planes; one in axial tension and the others in shear. The resistance of the plate for block shear rupture shall be taken as:

- If $A_n \geq 0.58A_{vn}$, then $R_r = 0.85(0.58F_y A_{vg} + F_u A_m)$ (4)

- Otherwise: $R_r = 0.85(0.58F_u A_{vn} + F_y A_{tg})$ (5)

Where:

0.85 = resistance factor for block shear. This ratio is calculated as the LRFD resistance factor for net section tension fracture (0.8) divided by the resistance factor for gross section tension yielding (0.95)

A_{vg} = gross area along the plane resisting shear stress

A_{tg} = gross area along the plane resisting tension stress

A_{vn} = net area along the plane resisting shear stress

- A_m = net area along the plane resisting tension stress
- F_y = minimum yield strength of the plate, as specified in AASHTO Table 10.2A
- F_u = minimum tensile strength of the plate, as specified in AASHTO Table 10.2A

The analysis of block shear rupture involves the evaluation of several patterns of planes to arrive at the governing pattern. Figure 3 provides some examples of potential block shear rupture planes for gusset plates in tension.

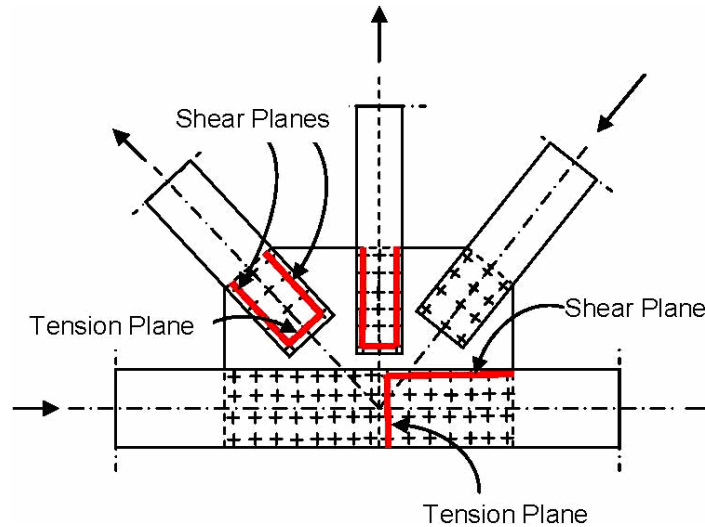


Figure 3 – Examples of potential block shear rupture planes for gusset plates in tension

GUSSET PLATES SUBJECT TO SHEAR

The shear resistance, R_r , for gusset plates subject to shear shall be taken as the lesser of the shear yield and the shear fracture resistance specified in Equations 6 and 7, respectively:

$$R_r = 0.58F_y A_g \times \Omega \quad (6)$$

$$R_r = 0.85 \times 0.58F_u A_n \quad (7)$$

where:

0.85 = resistance factor for shear fracture on the net section. This ratio is calculated as the LRFD resistance factor for net section tension fracture (0.8) divided by the resistance factor for gross section tension yielding (0.95)

- A_g = gross area of the plates resisting shear
- A_n = net area of the plates resisting shear
- F_y = minimum yield strength of the plates
- F_u = minimum tensile strength of the plates
- Ω = reduction factor taken as:

- $\Omega = 1.00$ for the case of uniform shear stress distribution where the gusset plates are of ample stiffness to prevent buckling and develop the plastic shear force of the plates, or
- $\Omega = 0.74$ for the case of flexural shear stress distribution, and in the absence of a more rigorous analysis or criterion to assure and quantify the stiffness requirements to develop the plastic shear force of the plates.

The analysis of gusset plates for shear involves the evaluation of several shear sections to arrive at the governing section. Figures 4 and 5 provide examples of shear sections to be evaluated in gusset plates in gross section shear yielding and net section shear fracture.

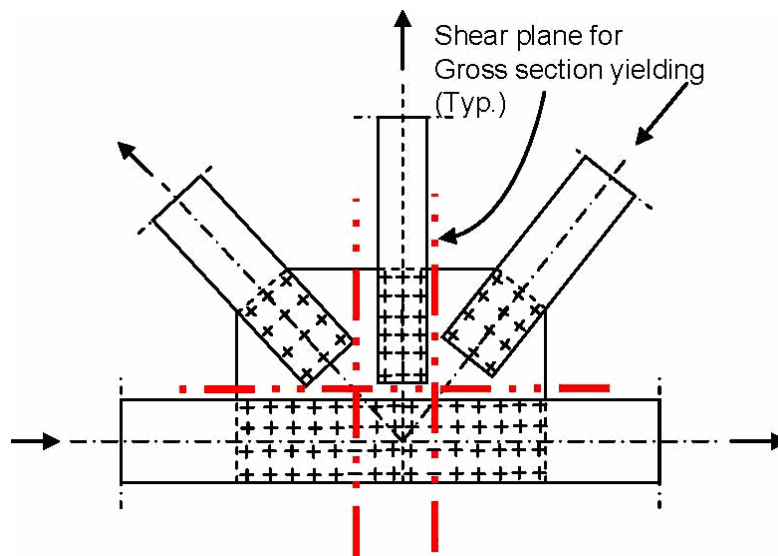


Figure 4 – Examples of gross section shear yielding planes

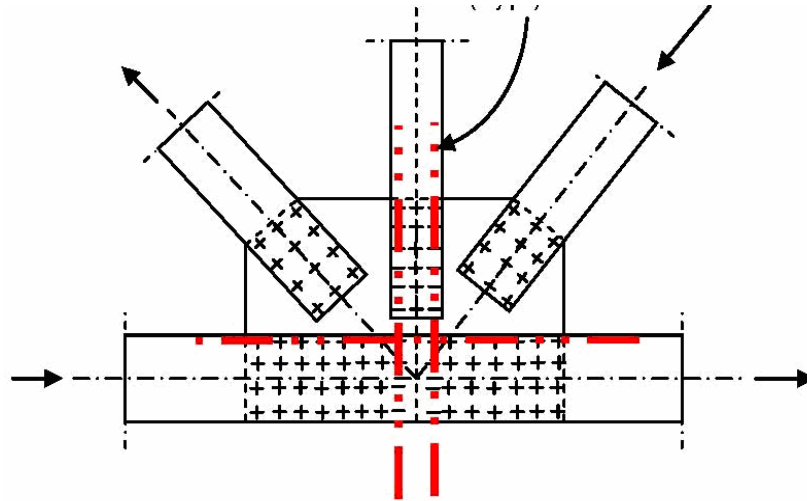


Figure 5 – Examples of net section shear fracture planes

GUSSET PLATES IN COMPRESSION

The proximity of connected members, complex state of stress, and boundary conditions can influence the resistance of gusset plates in compression. Therefore, special care must be exercised to properly assess the buckled shape and compressive resistance of gusset plates in compression.

In the absence of a more rigorous analysis, the resistance of gusset plates in compression may be determined as that of idealized members in compression, in accordance with the provisions of AASHTO Article 10.54.1.1. The unbraced length, L_c , may be determined as the distance between the last row of fasteners in the compression member under consideration and the first row of fasteners in the closest adjacent member measured along the line of action of the compressive axial force.

When lateral sway of gusset plates is possible, the effective length factor, K , for gusset plates may be taken from Table 2 for Cases (d), (e), or (f), depending on the anticipated buckled shape. When lateral sway of gusset plates is not possible, the effective length factor, K , for gusset plates may be taken from Table 2 for Cases (a), (b), or (c), as appropriate.

The effective width of the idealized compression member may be determined in accordance with the Whitmore method. Figure 6 provides an example showing the unbraced length and effective width for a gusset plate in compression.

Table 2 – K Values

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Design K value	0.65	0.80	1.0	1.2	2.1	2.0

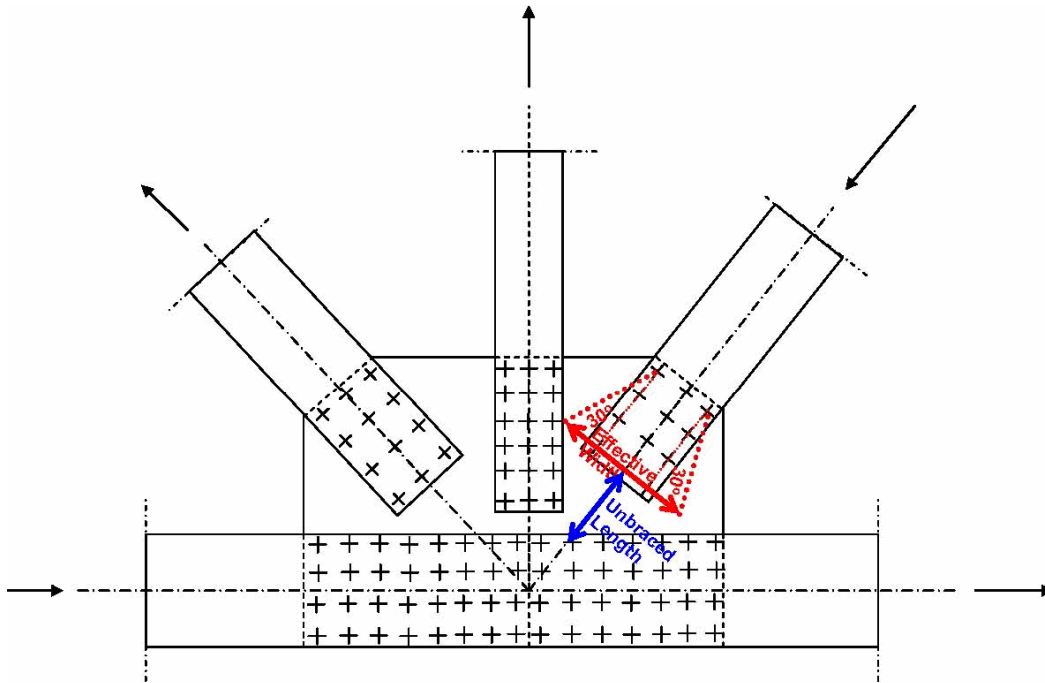


Figure 6 – Example showing the unbraced length and the effective width for a gusset plate in compression

GUSSET PLATES UNDER COMBINED FLEXURAL AND AXIAL LOADS

The resistance for gusset plates subject to combined flexural and axial stresses on the gross area of the plate may be taken as F_y .

where:

F_y = minimum yield strength of the plate. Gusset plates behave as deep members and; therefore, the application of flexural theory to gusset plates may not be applicable. Therefore, the combined flexural and axial stress at the extreme fiber is simplified and limited to F_y .

The analysis of gusset plates for combined flexural and axial loads involves the evaluation of several sections to arrive at the critical section. Figure 7 provides examples of sections to be evaluated in gusset plates under combined flexure and axial loads. Note that the sections in Figure 7 are placed such that the applied eccentricity is maximized.

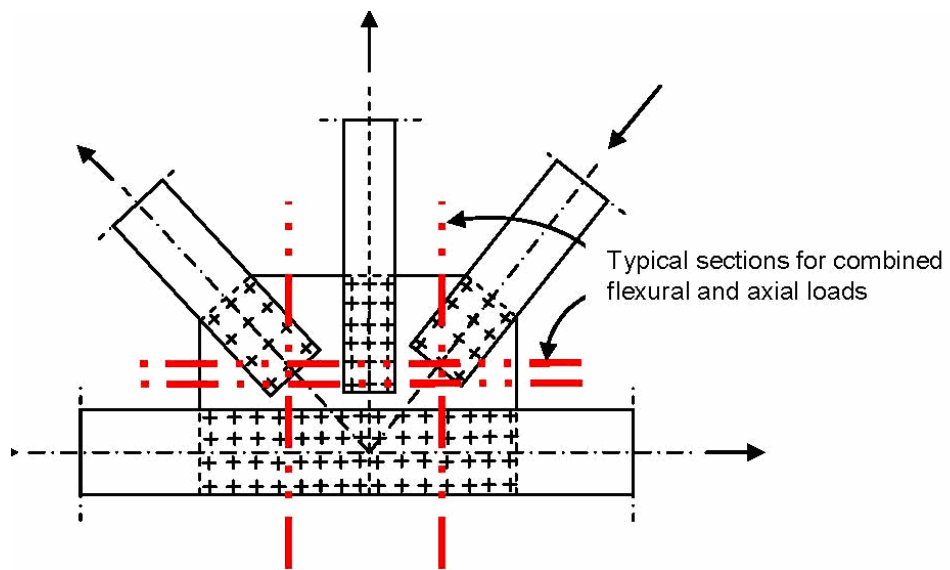


Figure 7 – Examples of combined flexural and axial load planes