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 resistance 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 the strength limit state only. Owners may require that connections be checked at other limit states such as the service limit state to minimize serviceability problems.

**RESISTANCE OF FASTENERS:**

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

The bolts in bolted gusset connections shall be evaluated to prevent bolt shear and plate bearing failures at the strength limit state. At the strength limit state, the provisions of AASHTO LRFD Article 6.13.2.7 and 6.13.2.9 shall apply for determining the resistance of bolts to prevent bolt shear and plate bearing failures.

The rivets in riveted gusset connections shall be evaluated to prevent rivet shear and plate bearing failures at the strength limit state. The plate bearing resistance for riveted connections shall be in accordance with AASHTO LRFD Article 6.13.2.9 for bearing at bolt holes.

The factored shear resistance of one rivet shall be taken as:

\[
\phi R = \phi F m A_r
\]

(1)

where:

\(\phi F\) \quad \text{Factored shear strength of rivet. The values in the table below may be used for } \phi F
Rivet Type or Year of Construction | $\phi F$ ksi
--- | ---
Constructed prior to 1936 or of unknown origin | 18
Constructed after 1936 but of unknown origin | 21
ASTM A 502 Grade I | 27
ASTM A 502 Grade II | 32

$m = \text{The number of shear planes}$

$A_r = \text{Cross-sectional area of the rivet before driving}$

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 three conditions:

- Yield on the gross section,
- Fracture on the net section, and
- Block shear rupture

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

**Gross Section Yielding Resistance**

$$P_r = \phi_y P_{ny} = \phi_y F_y A_g$$  \hspace{1cm} (2)

**Net Section Fracture Resistance**

$$P_r = \phi_u P_{nu} = \phi_u F_u A_n U$$  \hspace{1cm} (3)

where:

- $\phi_y = \text{resistance factor for tension yielding} = 0.95$
- $\phi_u = \text{resistance factor for tension fracture} = 0.80$
- $P_{ny} = \text{nominal tensile resistance for yielding in gross section}$
- $A_g = \text{gross cross-sectional area of the member}$
- $A_n = \text{net area of the member as specified in AASHTO LRFD Article 6.8.3.}$

The effective width shall be determined by the Whitmore method explained in this Guidance.
When determining the gross and net section areas, the effective width of the gusset plate in tension should 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 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 factored resistance of the plate for block shear rupture shall be taken as:

- If \( A_{\text{tg}} \geq 0.58 A_{\text{tn}} \), then: \( R_r = \phi_{bs} \left( 0.58 F_y A_{\text{tg}} + F_u A_{\text{tn}} \right) \) (4)
- Otherwise: \( R_r = \phi_{bs} \left( 0.58 F_u A_{\text{tn}} + F_y A_{\text{tg}} \right) \) (5)

where:

- \( \phi_{bs} \) = resistance factor for block shear = 0.80
- \( A_{\text{tg}} \) = gross area along the plane resisting shear stress
- \( A_{\text{tn}} \) = gross area along the plane resisting tension stress
- \( A_{\text{yn}} \) = net area along the plane resisting shear stress
- \( A_{\text{tn}} \) = net area along the plane resisting tension stress
- \( F_y \) = specified minimum yield strength of the plate
- \( F_u \) = specified minimum tensile strength of the plate
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.

![Diagram of gusset plates with shear planes and tension planes]

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

**GUSSET PLATES SUBJECT TO SHEAR**

The factored 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:

$$R_r = \phi_{vy} R_n = \phi_{vy} \times 0.58 A_g F_y \times \Omega \quad (6)$$

$$R_r = \phi_{vu} R_n = \phi_{vu} \times 0.58 A_n F_u \times \Omega \quad (7)$$

where:

- $\phi_{vy}$ = resistance factor for shear yielding on the gross section = 0.95
- $\phi_{vu}$ = resistance factor for shear fracture on the net section = 0.80
- $R_n$ = nominal resistance in shear
- $A_g$ = gross area of the plates resisting shear
- $A_n$ = net area of the plates resisting shear
- $F_y$ = specified minimum yield strength of the plates
- $F_u$ = specified minimum tensile strength of the plates
- $\Omega$ = 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](image)

![Figure 5 – Examples of net section shear fracture planes](image)
GUSSSET 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 LRFD Articles 6.9.2.1 and 6.9.4.1. The unbraced length 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. The effective length factor, K, for gusset plates may be taken as K = 1.0 or K = 2.0, depending on the anticipated buckled shape shown in AASHTO LRFD Table C4.6.2.5-1. 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.

![Figure 6 – Example showing the unbraced length and the effective width for a gusset plate in compression](image-url)
GUSSET PLATES UNDER COMBINED FLEXURAL AND AXIAL LOADS

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

where:

$\phi_f = $ resistance factor for flexure = 1.00
$F_y = $ specified minimum yield strength of the plate

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](image_url)