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PennDOT Truss Gusset Plate Analysis and Ratings Spreadsheet

General Instructions

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1 General Notes and Assumptions

- This spreadsheet is intended to be used for the analysis and rating of typical truss gusset plates in order to investigate the existence of a design flaw with respect to gusset plate thickness.

- Refer to FHWA Bridge Design Guidance No. 1 Part B - Load Rating Evaluation of Gusset Plates in Truss Bridges, August 28, 2008 Revision, for additional information.

- Operating Level rating is determined.

- The bearing on the fasteners at the joint is not investigated, only bearing on the connected material.

- The effective length factor, K, used in the column capacity equation for the unsupported length at the end of the compression diagonal is taken to be 2.0 if the gusset plate analysis shows that the plate has yielded due to shear on Section A-A, otherwise it is taken as 1.2. (See AASHTO Standard Specifications Appendix C Table C.1)

- Consider the following for joints with no diagonal members framing in (i.e. post and hanger locations):

  The axial force in the top and bottom chords does not transfer to the gusset plates where only a vertical member frames in and the chords are continuous through the joint; the axial force is carried by the chord, not the gusset. If there are splice plates connecting two chord members at these locations, the splice plates take a majority of the loading; therefore, the axial force carried by the gusset plates is very minimal. Investigate only Section A-A for the joints with no diagonals except at supports where engineering judgment should be used. For more information, go to **Guide \ Method of Solution** menu.

2 BAR7 Selected Inputs for Gusset Plate Evaluation

2.1 "Project Identification" Input Card Selected Input Value

"Lanes" ->	D	Allow the program to determine the controlling number of design lanes to maximize the forces in the truss members
"Live Load" ->	A	Consider the H20 loading only
	B	Consider the HS20 loading only
	C	Consider the ML80 loading only
	D	Consider the P-82 loading only
	T	Consider the TK527 loading only
	Special LL No.	Special user defined live load vehicle (See Section 5.19 in BAR7 users manual)

Note: Only BAR7 output due to single live load case may be used by this program, therefore, please select one of the above codes. This program can only analyze one live load case at a time; additional live load cases will have to be run by copying the original spreadsheet and importing the additional BAR7output files.

"Output" -> 3 Truss member forces are included in the output

3 Gusset Plate Program Required Input Description

Bridge Name -> Self explanatory

BMS# -> Self explanatory

By: -> Self explanatory

CHKD.By: -> Self explanatory

Note: As necessary, refer to **Guide \ Figures** for clarification regarding the following input information.

3.1 Gusset Plate

Gusset Plate Location -> U10, L11, etc. (Automatically inserted based on BAR7 labeling when BAR7 is used, otherwise user must manually input (i.e for STAAD, etc.)

F_y -> specified minimum yield stress of the gusset plate material, ksi

t -> thickness of the gusset plate, in.
If there are two gusset plates per side, then input the total thickness of the two plates (See Figure 7, Section C-C)

h_A -> length of the gusset plate along a horizontal cut at or near the edge of the chord (i.e. Figure 1 – 4, Section A-A), in.
Input the length of the larger plate if two gusset plates are used per side.

h_B -> length of the gusset plate along a vertical cut on the Section B-B side of the vertical member (i.e. Figure 1 – 4, Section B-B), in.
Input the length of the larger plate if two gusset plates are used per side.

h_C -> length of the gusset plate along a vertical cut on the Section C-C side of the vertical member (i.e. Figure 1 – 4, Section C-C), in.
Input the length of the larger plate if two gusset plates are used per side.

e_A -> vertical distance from the line of action in the chord to the edge of the chord adjacent to the diagonal/vertical members, in.
(i.e. this distance defines where Section A-A is taken).Typically taken as "W/2".
Used to calculate the bending moment on the horizontal cut at Section A-A due to the vertical component of the diagonal.

e_B -> distance from the line of action in the vertical member to the edge of the vertical member, in.
Used to calculate the bending moment on the vertical cut at Section B-B due to the horizontal component of the diagonal.

e_C -> distance from the line of action in the vertical member to the edge of the vertical member, in.
Used to calculate the bending moment on the vertical cut at Section C-C due to the horizontal component of the diagonal.

b -> maximum unsupported length along the edge of the gusset plate to check against 11,000 / $\sqrt{F_y}$, in.
For post and hanger type gusset plates, b may be taken as zero in most cases. (See Deck Truss Example and Figures 1-4)

3.2 Fasteners

F_{v_ASD} -> The connection is checked as bearing-type (i.e. the connection has slipped), therefore, input the Operating Level capacities for the bolts or rivets for the ASD analysis (AASHTO Manual for Condition Evaluation of Bridges Tables 6.6.2.1-3 and 6.6.2.1-4 may be used when applicable), ksi

F_{v_LFD} -> The connection is checked as bearing-type (i.e. the connection has slipped), therefore, input the bolt or rivet capacities using Table 10.56A for rivets, low-strength bolts, and high strength bolts from the AASHTO Standard Specifications whenever applicable, ksi

d -> minimum nominal diameter of the fasteners at the joint, in.

3.3 Members

Note: When manually inputting the axial forces from STAAD or other software, conservatively match the sign of the Live Load axial force with the sign of the Dead Load axial force. Note that there will be isolated cases where the live load axial force of opposite sign will be vastly larger than the Dead Load axial force, in these cases, input the larger Live Load axial force regardless if it matches the sign of the Dead Load.

(Ex. DL = 20 k, LL_{compr} = -206 k and $LL_{tension}$ = 150 k; therefore, DL + LL_{compr} = -186 k and DL + $LL_{tension}$ = 170 k)

DL_1 -> maximum dead load axial force in member 1, kips
(This input description is used for informational purposes when using BAR7 output)

$LL+I_1$ -> maximum live load (plus impact) axial force in member 1, kips
(This input description is used for informational purposes when using BAR7 output)

W_1 -> distance between outermost rows of fasteners measured perpendicular to the line of action on member 1, in.

L_1 -> distance between the first and last row of fasteners in member 1, in.

N_{t1} -> number of fasteners across the width of the member
(i.e. perpendicular to the line of action of the member)

N_{L1} -> number of fasteners along the length of the member
(i.e. parallel to the line of action of the member)

θ_1 -> angle measured from a vertical line at the centerline of the gusset to the line of action of member 1, degrees (See Figures 1-4)
(This input description is used for informational purposes when using BAR7 output)

DL_2 -> maximum dead load axial force in member 2, kips
(This input description is used for informational purposes when using BAR7 output)

$LL+I_2$ -> maximum live load (plus impact) axial force in member 2, kips
(This input description is used for informational purposes when using BAR7 output)

W_2 -> distance between outermost rows of fasteners measured perpendicular to the line of action on member 2, in.

L_2 -> distance between the first and last row of fasteners in member 2, in.

N_{t2} -> number of fasteners across the width of the member
(i.e. perpendicular to the line of action of the member)

N_{L2} -> number of fasteners along the length of the member
(i.e. parallel to the line of action of the member)

θ_2 -> angle measured from a vertical line at the centerline of the gusset to the line of action of member 2, degrees (See Figures 1-4)
(This input description is used for informational purposes when using BAR7 output)

DL_3 -> maximum dead load axial force in member 3, kips
(This input description is used for informational purposes when using BAR7 output)

$LL+I_3$ -> maximum live load (plus impact) axial force in member 3, kips
(This input description is used for informational purposes when using BAR7 output)

W_3 -> distance between outermost rows of fasteners measured perpendicular to the line of action on member 3, in.

L_3 -> distance between the first and last row of fasteners in member 3, in.

N_{t3} -> number of fasteners across the width of the member
(i.e. perpendicular to the line of action of the member)

N_{L3} -> number of fasteners along the length of the member
(i.e. parallel to the line of action of the member)

θ_3 -> angle measured from a vertical line at the centerline of the gusset to the line of action of member 3, degrees (See Figures 1-4)
(This input description is used for informational purposes when using BAR7 output)

L_{c3} -> unsupported length between the last row of fasteners for the diagonal in compression and the first row of fasteners in the chord measured along the line of action of the diagonal, in. Leave blank if this is the tension diagonal.
(See Method of Solution, Section 4.2)

DL_4 -> maximum dead load axial force in member 4, kips
(This input description is used for informational purposes when using BAR7 output)

$LL+I_4$ -> maximum live load (plus impact) axial force in member 4, kips
(This input description is used for informational purposes when using BAR7 output)

W_4 -> distance between outermost rows of fasteners measured perpendicular to the line of action on member 4, in.

L_4 -> distance between the first and last row of fasteners in member 4, in.

N_{t4} -> number of fasteners across the width of the member
(i.e. perpendicular to the line of action of the member)

N_{L4} -> number of fasteners along the length of the member
(i.e. parallel to the line of action of the member)

L_{c4} -> unsupported length between the last row of fasteners for the vertical in compression and the first row of fasteners in the chord measured along the line of action of the vertical, in. Leave blank if this is the tension vertical.
(See Method of Solution, Section 4.2)

DL_5 -> maximum dead load axial force in member 5, kips
(This input description is used for informational purposes when using BAR7 output)

$LL+I_5$ -> maximum live load (plus impact) axial force in member 5, kips
(This input description is used for informational purposes when using BAR7 output)

W_5 -> distance between outermost rows of fasteners measured perpendicular to the line of action on member 5, in.

L_5 -> distance between the first and last row of fasteners in member 5, in.

N_{t5} -> number of fasteners across the width of the member
(i.e. perpendicular to the line of action of the member)

N_{L5} -> number of fasteners along the length of the member
(i.e. parallel to the line of action of the member)

θ_5 -> angle measured from a vertical line at the centerline of the gusset to the line of action of member 5, degrees (See Figures 1-4)
(This input description is used for informational purposes when using BAR7 output)

L_{c5} -> unsupported length between the last row of fasteners for the diagonal in compression and the first row of fasteners in the chord measured along the line of action of the diagonal, in. Leave blank if this is the tension diagonal.
(See Method of Solution, Section 4.2)

3.4 Total Number of Fasteners

(Entered under optional input information)

Note: This information is required if $N_{t\#} \times N_{L\#} \neq N_{T\#}$.

N_{T1} -> total number of fasteners connecting member 1 to gusset plate

N_{T2} -> total number of fasteners connecting member 2 to gusset plate

N_{T3} -> total number of fasteners connecting member 3 to gusset plate

N_{T4} -> total number of fasteners connecting member 4 to gusset plate

N_{T5} -> total number of fasteners connecting member 5 to gusset plate

4 Optional Input Information

Note: This information is generally only needed if deficiencies are encountered after the initial analysis run, which is based on the required inputs.

4.1 Splice Size

4.1.1 Outside

t_{s1} -> outside splice plate thickness used to increase the net area in tension, in. If tension deficiencies are encountered in the tension chord after the initial analysis, the contribution of this plate to the net area may be included. (See Figure 6)

l_{s1} -> outside splice plate length when present, in. (See description for t_{s1} for more information)

4.1.2 Inside

t_{s4} -> inside splice plate thickness when present, in. (See description for t_{s1} for more information)

l_{s4} -> inside splice plate length when present, in. (See description for t_{s1} for more information)

4.1.3 Top

t_{s2} -> top splice plate thickness when present, in. If tension deficiencies are encountered in the tension chord after the initial analysis, the contribution of this plate, with respect to reducing the chord tension force, will be included when this value is input. In addition to this force reduction, the splice plates are used to add to the tension area for the block shear analysis. (See Figure 6)

w_{s2} -> top splice plate width when present, in. (See description for t_{s2} for more information)

l_{s2} -> top splice plate length when present, in. (See description for t_{s2} for more information)

4.1.4 Bottom

t_{s3} -> bottom splice plate thickness when present, in. (See description for t_{s2} for more information)

w_{s3} -> bottom splice plate width when present, in. (See description for t_{s2} for more information)

l_{s3} -> bottom splice plate length when present, in. (See description for t_{s2} for more information)

4.2 Concurrent Axial Live Load

Notes:
- This input item is not valid when using BAR7 output.
- Only one member will experience the maximum axial live load force at any given time, all other member axial forces will be concurrent to the maximum member force.
- The maximum axial forces in each member ("green region") are still required input. The concurrent loads are only used for shear analyses on Sections A-A, B-B, and C-C.

LL_1+I_1 -> maximum or concurrent live load (plus impact) axial force in member 1, kips

LL_2+I_2 -> maximum or concurrent live load (plus impact) axial force in member 2, kips

LL_3+I_3 -> maximum or concurrent live load (plus impact) axial force in member 3, kips

LL_4+I_4 -> maximum or concurrent live load (plus impact) axial force in member 4, kips

LL_5+I_5 -> maximum or concurrent live load (plus impact) axial force in member 5, kips

4.3 Tensile Stress

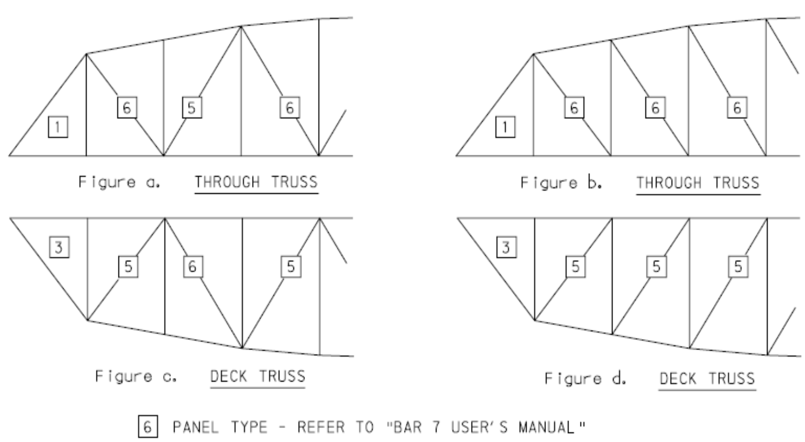
Note: 1.4 F_y is used as a default value if F_u was not input.

F_u -> specified minimum tensile stress of the gusset plate material, ksi

5 Instructions for processing the input information

- **If using axial forces determined by BAR7 computer software, use the following procedure:**

Step 1: Create the BAR7 output file(s) incorporating the modifications described at the beginning of these instructions. The output file must have the extension ".OUT" in order to be used by this spreadsheet. Note that the spreadsheet can only calculate the member angles for panel types 1, 3, 5, and 6 (BAR7 manual Figure 5.11.2). See figure a, b, c, & d for examples.



Step 2: On the **Import** menu of this spreadsheet, point to **Import BAR7 Output Data** submenu, and then select one case from the following:

Case 1 – Sign of LL Match Sign of DL

When selected, the program will extract the live load plus impact axial force with the same sign as the dead load. **Suggested starting point.**

Case 2 – DL with LL Always in Compression

When selected, the program will extract the live load plus impact axial force from the compression column regardless of the sign of the dead load.

Case 3 – DL with LL Always in Tension

When selected, the program will extract the live load plus impact axial force from the tension column regardless of the sign of the dead load.

Step 3: Locate the BAR7 output file that will be imported into the spreadsheet and click "Save". Confirm that this is the correct file to be imported.

Step 4: If the variables of "H3" in the BAR7 Truss Geometry section are all zeros, then the spreadsheet will ask if this bridge is a deck-type truss (as opposed to a through-type truss), click yes or no. The question is asked so that the assumed joint configurations shown in the figures are consistent with the extracted axial forces and angles.

The spreadsheet will then import the joint labels, axial forces and angles, θ.

Step 5: Input the remaining information into "Input" tab

Step 6: Once all required input are entered into "Input" tab, to run the spreadsheet, go to **Run** menu and select one the following run options.

1) Perform Analysis to Obtain Governing Operating Ratings

This option is the suggested starting point. The spreadsheet will run through Cases 1 – 3 to determine the governing operating ratings. Once the governing ratings are calculated, the Case 1 BAR7 results will be shown on all tabs by default.

2) Perform Analysis and Ratings on Current Case

If the axial forces are manually entered by the user (i.e. STAAD, etc.), the spreadsheet will simply use the values input for the analysis and ratings. This option is also valid when BAR7 output is used; it is included in the event that the user would like to investigate the individual case analysis and rating results instead of the overall governing results.

- **If using axial forces determined by STAAD or some other computer software, use the following procedure:**

Step 1: Input all of the above information into the “Input” tab.

Step 2: Once all required input is entered into the “Input” tab, to run the spreadsheet, go to the **Run** menu and select one the following run options.

1) Perform Analysis to Obtain Governing Operating Ratings
Since all of the entered values are user input, the spreadsheet will simply run the analysis and ratings.

2) Perform Analysis and Ratings on Current Case
If the axial forces are manually entered by the user (i.e. STAAD, etc.), the spreadsheet will simply use the values input for the analysis and ratings.

6 Post processing the results

Note: Verify that the Operating Level Ratings for all gusset plates are above 1.0 on the "Summary" tab. Investigate the locations that are shown as deficient and use engineering judgment to determine the validity of the deficient rating factor. Re-run the analysis with the optional information when deemed necessary.

General:

- Green Colored Font denotes that the analysis check is OK and/or Operating Level rating factor is greater than or equal to 1.0.
- Red Colored Font denotes that the analysis check is No Good and/or Operating Level rating factor is less than 1.0.

6.1 Shear@Sec.A-A, …B-B, …C-C Tabs:

- Shear Capacity Results

g : denotes that shear on the gross section governs
n : denotes that shear on the net section governs

6.2 Ten. & Comp. Tab:

- Member Capacity Results

T : tension capacity shown
C : compression capacity shown
g : axial force applied to gross section governs
n : axial force applied to net section governs

6.3 Block Shear Tab:

- "Axial Load" heading

T : tension member
C : compression member

- Capacity Results

B1 : block shear Case 1 (see Figure 8) yields governing capacity for block shear check
B2 : block shear Case 2 (see Figure 8) yields governing capacity for block shear check
B3 : block shear Case 3 (see Figure 8) yields governing capacity for block shear check

6.4 Connections Tab:

- "Axial Load" heading

T :	tension member
C :	compression member

- "Capacity" heading

FS :	fastener shear capacity governs
MB :	bearing on connected material capacity governs

6.5 Summary Tab:

- "Shear" heading

A :	denotes that governing result is from Section A-A analysis
B :	denotes that governing result is from Section B-B analysis
C :	denotes that governing result is from Section C-C analysis
g :	denotes that applied force on the gross section governs
n :	denotes that applied force on the net section governs

- "Tension" heading

M.# :	denotes what member governed

- "Compression" heading

M.# :	denotes what member governed

- "Block Shear" heading

M.# :	denotes what member governed
B.3 :	denotes that Case 3 (See Figure 8) governs

- "Connections" heading

M.# :	denotes what member governed

- "Critical Operating Rating" heading

Shear :	shear governs
Ten. :	stress at end of tension member governs
Comp. :	stress at end of compression member governs
Blks. :	block shear failure governs
Conn. :	connection strength governs