Streamlining Steel Truss Bridge and Gusset Plate Rating

2023 AASHTO RADBUG Meeting
Madison, WI
August 8-9, 2023

Load Rating Branch, Structure Maintenance & Investigation

California Department of Transportation

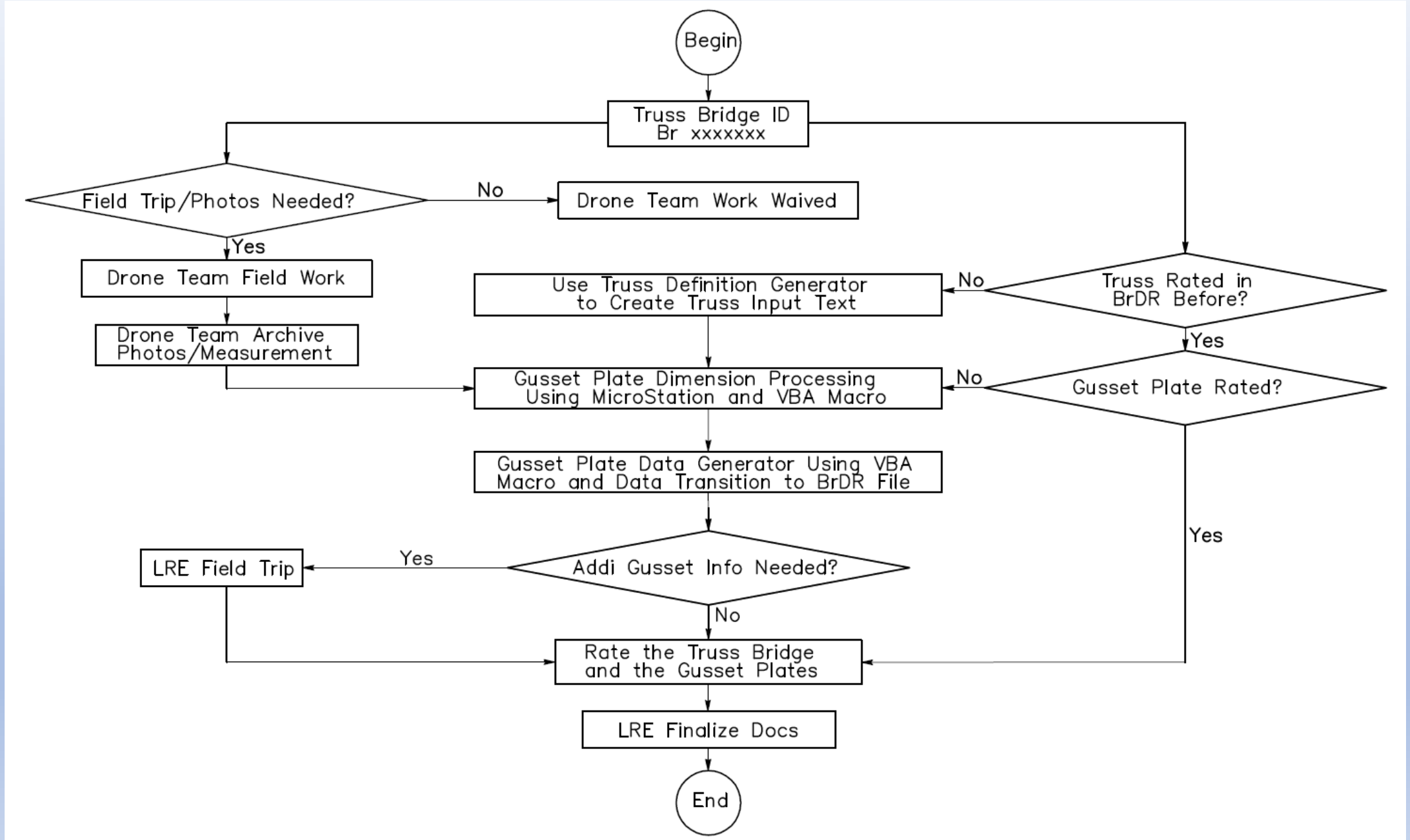
Current Status of Truss Bridge Rating in CA

- CA has more than 250 steel truss bridges (200+ local bridges, 40+ state-owned bridges), Most have been rated by using hand calculations, rating software, and other methods

- 171 truss bridges have been rated by using AASHTOWare BrDR for bridge members EXCEPT that not all analyses have included the gusset plate rating

- Currently, only a few truss bridges have been rated for bridge members AND the connections with gusset/splice plates by using AASHTOWare BrDR

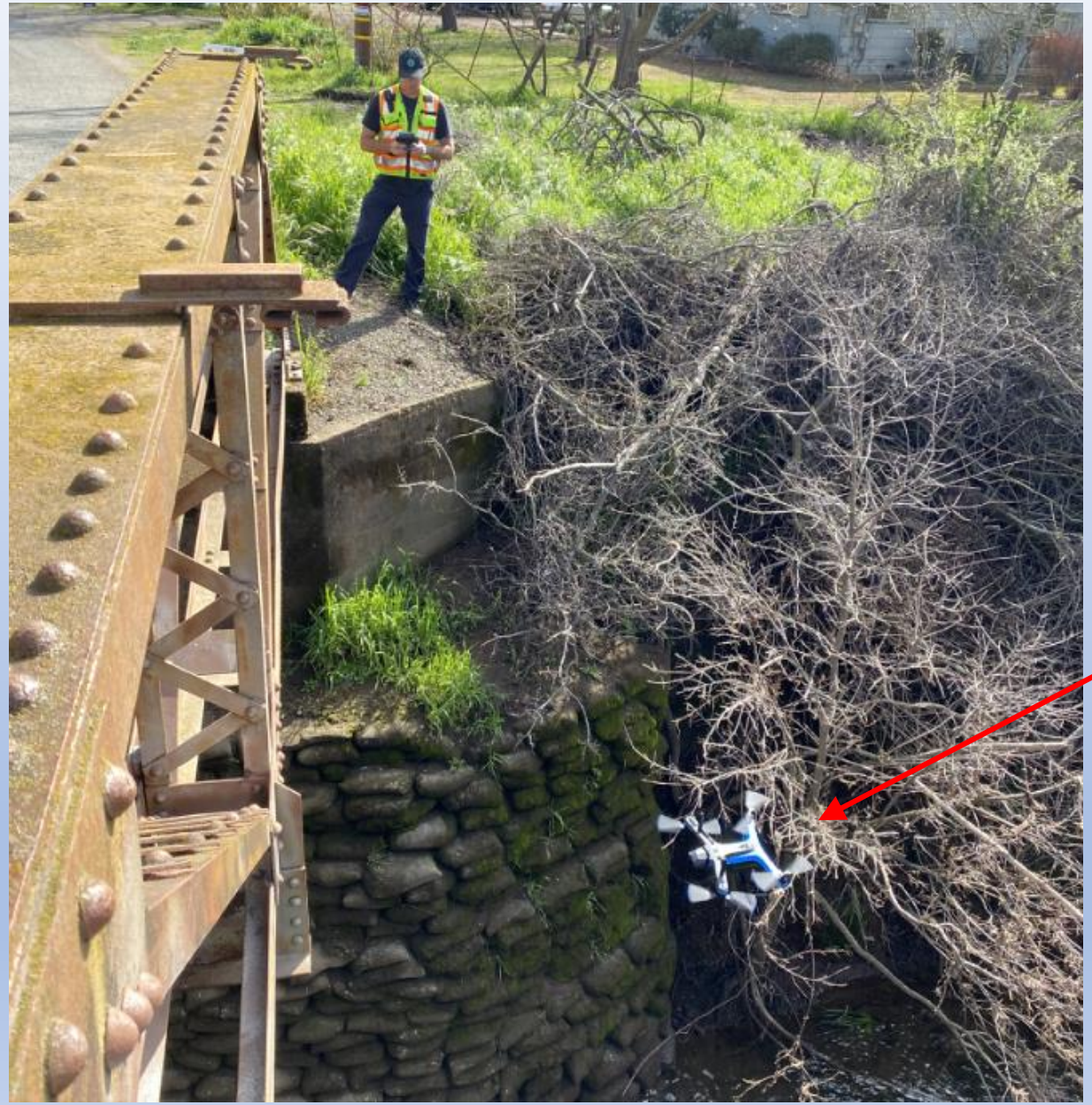
Flow Chart for Rating A Truss Bridge & Its Gusset Plates



Gusset Plate Information Collection

- As-built plans, shop drawings, and other archived files
- Drone photos
- Field measurement
- Bridge design/construction specifications, manuals, and other code regulations when the bridge was designed and built

Drone in the Air



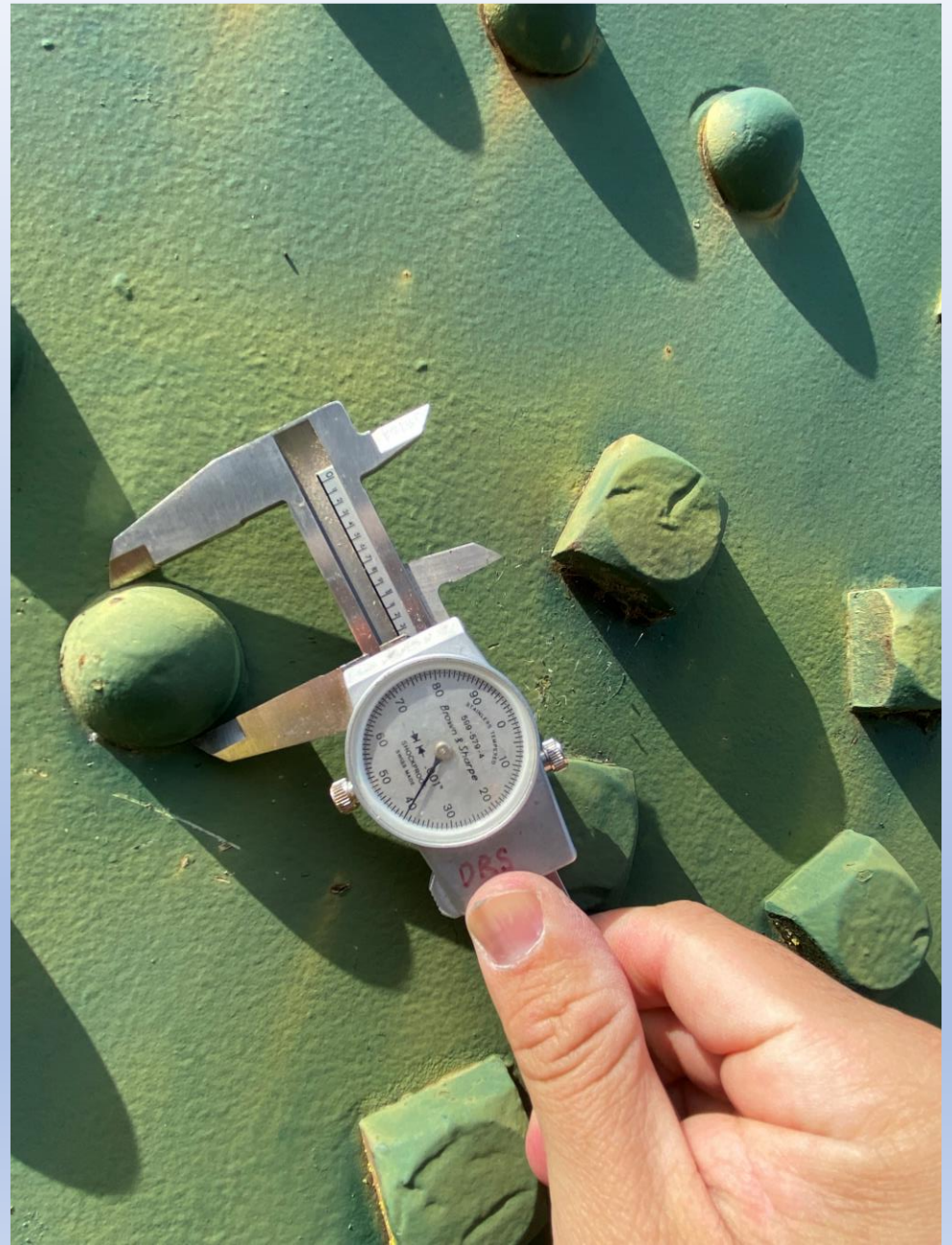
Drone Photo for Gusset Plate

Dimension Measurements in the Field

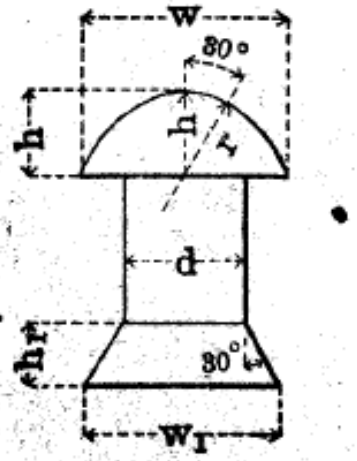
LRE Field Measurements/Investigations

Gusset Plate Height Measurement

Rivet Head Diameter Measurement



Rivet Diameter Derived from Head Size



Dimensions of Structural Rivets

	Diameter of Rivet, d, Inches									
	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
w	11/16	7/8	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16	2 3/8
h	5/16	3/8	7/16	1/2	5/8	11/16	3/4	7/8	15/16	1
r	7/16	9/16	11/16	13/16	15/16	1	1 1/8	1 1/4	1 3/8	1 1/2
w_1	9/16	3/4	1	1 3/16	1 3/8	1 9/16	1 3/4	2	2 3/16	2 3/8
h_1	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4

$w = 1\frac{1}{2}\,d + \frac{1}{8}''$ $\quad h = 0.425\,w$ $\quad r = 1\frac{1}{2}\,h.$

Plate Thickness Measurement

Truss Definition Text Input Generator

BrDR Truss Definition Text Generation

- Currently, Truss Input text (shown on right) can only be composed by LREs manually in BrDR 7.4

- Caltrans has developed an In-house tool – Truss Definition Generator (an excel file coded with VBA Macro)

- By using the Truss Definition Generator, truss input texts can be created by inputting control parameters

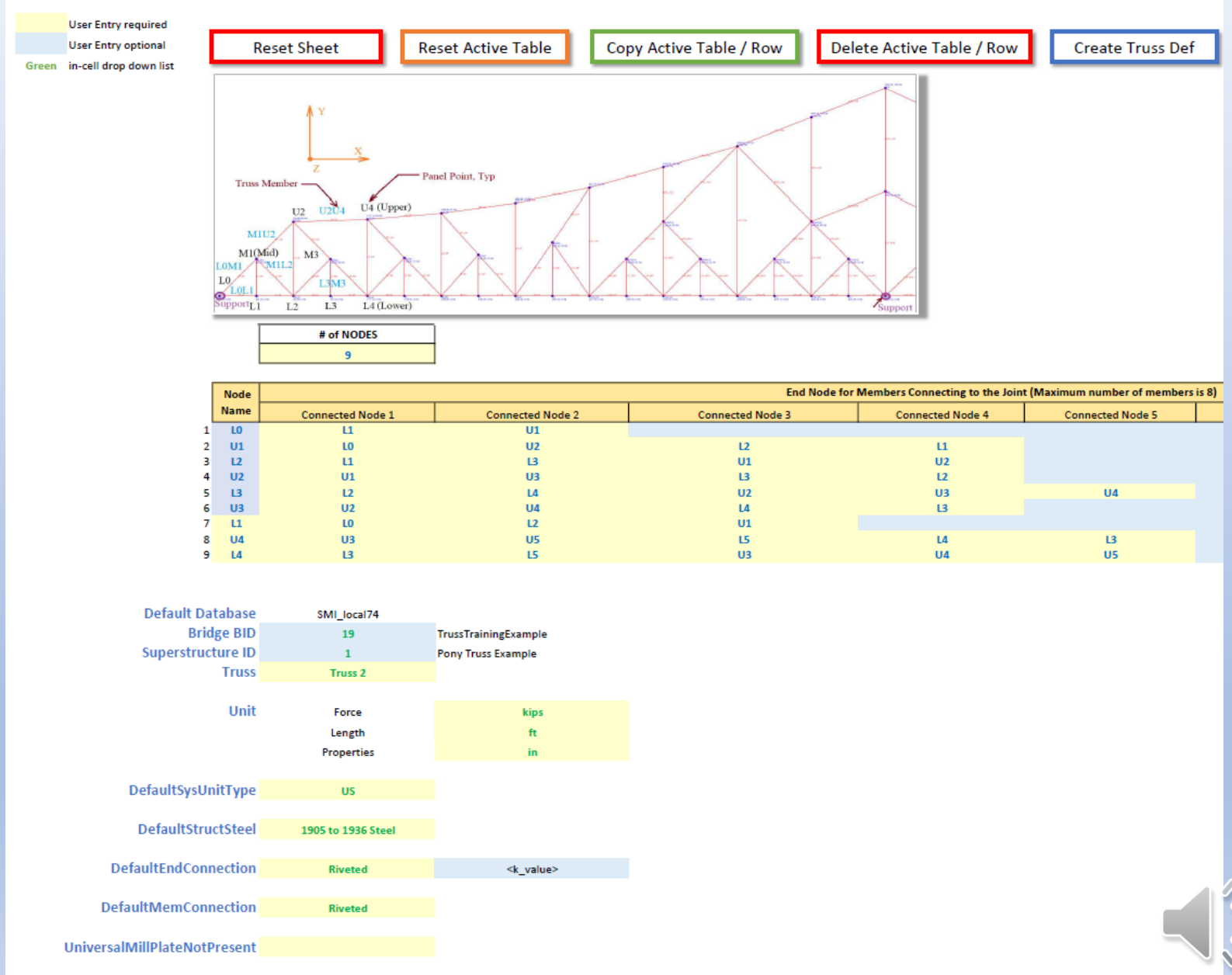
In-House Truss Text Input Generator 1

Procedures of Input Generator:

1. define nodes, and the connectivity

2. Define materials property

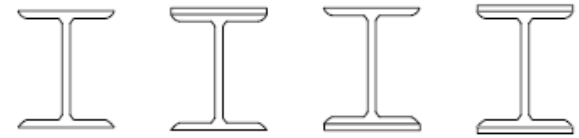
3. Define cross section (seen next slide)



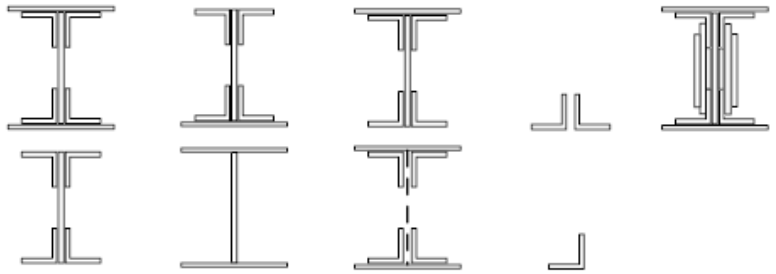
In-House Truss Text Input Generator 2

The following types of cross sections can be described.

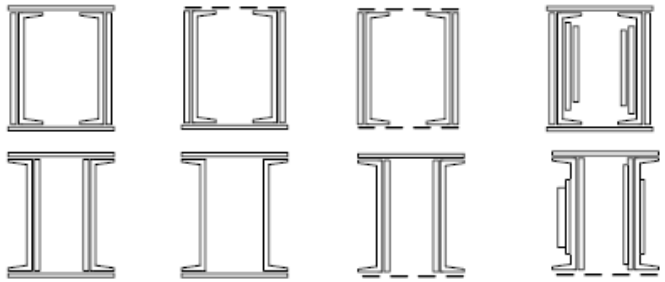
6.9.1 Rolled Section



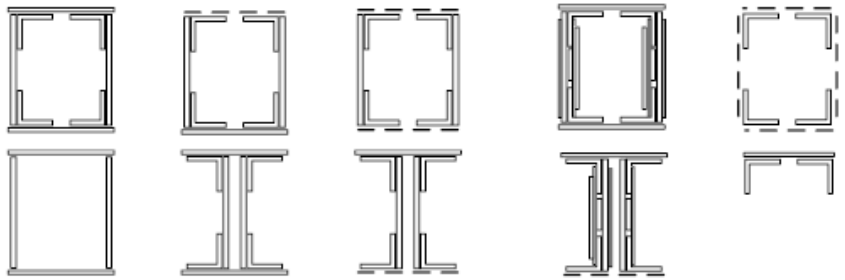
6.9.2 Builtup Section



6.9.3 Channel Box Section



6.9.4 Angle Box Section



1	ChannelBox	CB1	<comment>				
	TopFlangePlate	18	0.75	M1			
	BottomFlangePlate	18	0.75	M1			
	LeftWebPlate	15	1.5	M1			
	RightWebPlate	15	1.5	M1			
	LeftWebPlate2	1.5	8	M1			
	RightWebPlate2	1.5	8	M1			
	Channels	C 15x45	Outward	10	<material _name#>		
	Connection	Riveted	10.25				
	Lacing	Bottom					

1	AngleBox	AB1	<comment>				
	TopFlangePlate	25.25	0.625	M1			
	BottomFlangePlate	13.25	0.625	M1			
	LeftWebPlate	36	1.125	M1			
	RightWebPlate	36	1.125	M1			
	LeftWebPlate2	0.625	12.875	M1			
	RightWebPlate2	0.625	12.875	M1			
	TopAngles	L 3x2x1/4	Horizontal	Inward	<material _name#>		
	BottomAngles	L 3x2x1/4	Horizontal	Inward	<material _name#>		
	BackToBack	24.75	36				
	Connection	Bolted	19.125				
	Lacing						
	WebLacing	Right					

1	NonDetailed	<nickname>	<comment>				
	Gross Area, in2	Net_Area, in2	Material Name	Section Modulus zz, in3>	Section Modulus yy, in3	Section Modulus zz, in3	Section Modulus yy, in3
	20.05	15.78	M1	154.5	<iyy#, in3>	<szz#, in3>	<syy#, in3>

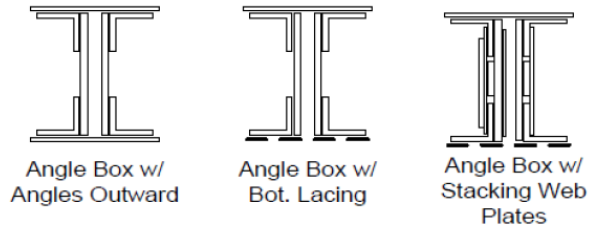
Symmetry	Even

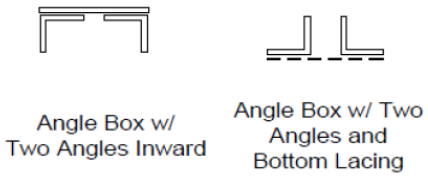
PanelPoint

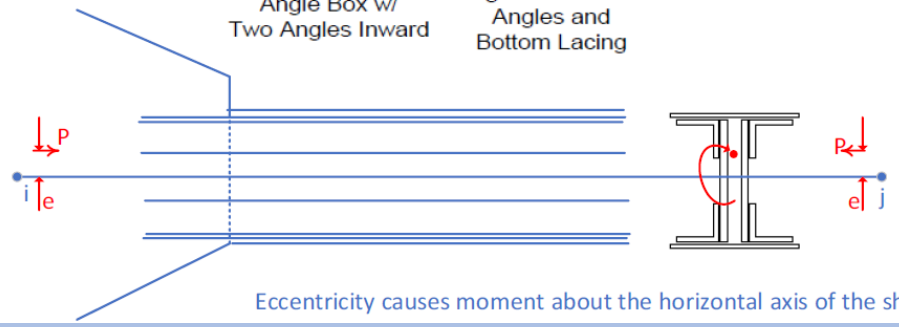
	Panel Point ID	Panel Point Type	X Coordinate, ft	Y Coordinate, ft
1	L0	Lower	0	0

Generate Truss Definition Text

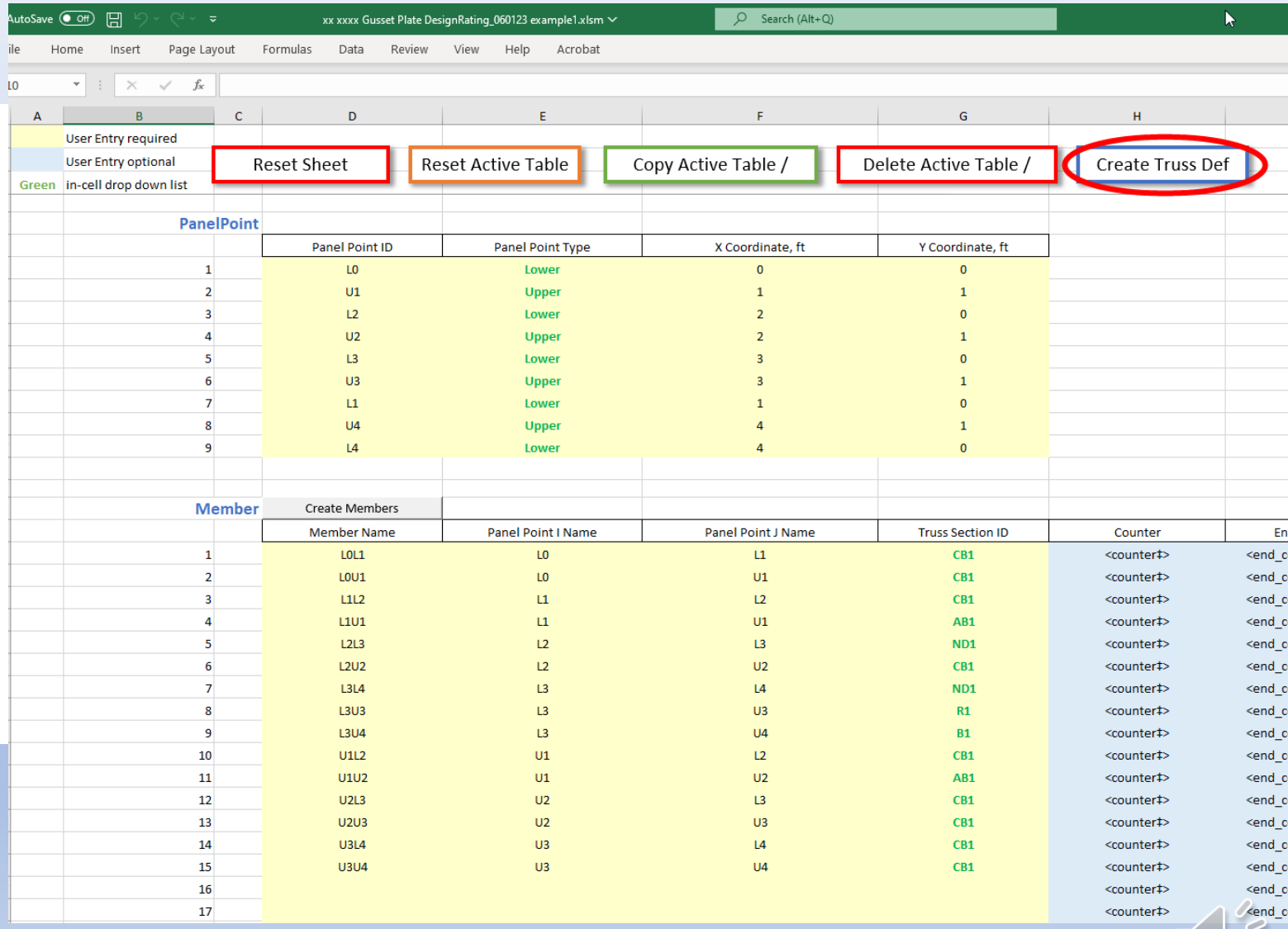
These angle box truss members are assumed to be attached to the gusset plate connections along the vertical legs of the angles.







Eccentricity causes moment about the horizontal axis of the shape.



AutoSave Off — xx xxxx Gusset Plate DesignRating_060123 example1.xlsm — Search (Alt+Q)

File Home Insert Page Layout Formulas Data Review View Help Acrobat

L0

User Entry required
User Entry optional
Green in-cell drop down list

Reset Sheet | Reset Active Table | Copy Active Table / | Delete Active Table / | Create Truss Def

PanelPoint

	Panel Point ID	Panel Point Type	X Coordinate, ft	Y Coordinate, ft
1	L0	Lower	0	0
2	U1	Upper	1	1
3	L2	Lower	2	0
4	U2	Upper	2	1
5	L3	Lower	3	0
6	U3	Upper	3	1
7	L1	Lower	1	0
8	U4	Upper	4	1
9	L4	Lower	4	0

Member — Create Members

	Member Name	Panel Point I Name	Panel Point J Name	Truss Section ID	Counter	En
1	L0L1	L0	L1	CB1	<counter‡>	<end_c
2	L0U1	L0	U1	CB1	<counter‡>	<end_c
3	L1L2	L1	L2	CB1	<counter‡>	<end_c
4	L1U1	L1	U1	AB1	<counter‡>	<end_c
5	L2L3	L2	L3	ND1	<counter‡>	<end_c
6	L2U2	L2	U2	CB1	<counter‡>	<end_c
7	L3L4	L3	L4	ND1	<counter‡>	<end_c
8	L3U3	L3	U3	R1	<counter‡>	<end_c
9	L3U4	L3	U4	B1	<counter‡>	<end_c
10	U1L2	U1	L2	CB1	<counter‡>	<end_c
11	U1U2	U1	U2	AB1	<counter‡>	<end_c
12	U2L3	U2	L3	CB1	<counter‡>	<end_c
13	U2U3	U2	U3	CB1	<counter‡>	<end_c
14	U3L4	U3	L4	CB1	<counter‡>	<end_c
15	U3U4	U3	U4	CB1	<counter‡>	<end_c
16					<counter‡>	<end_c
17					<counter‡>	<end_c

Generated Truss Definition Text for BrDR Input

TRUSS DEFINITION

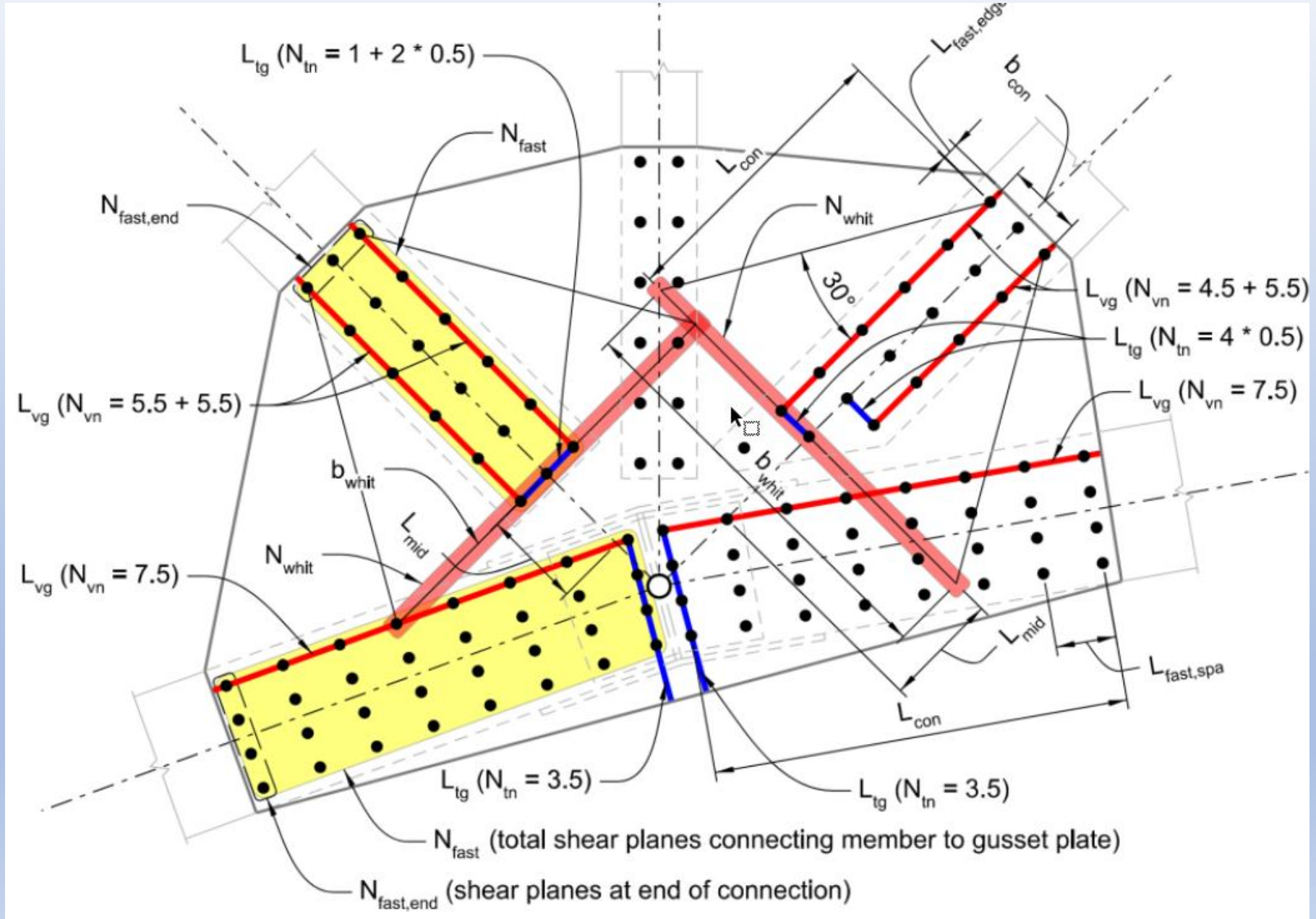
```
Truss "Truss 2"

Unit
Force kips
Length ft
Properties in

DefaultSysUnitType US

DefaultStructSteel "1905 to 1936 Steel"

DefaultEndConnection
Riveted

DefaultMemConnection Riveted

MaterialType
M1 = "1905 to 1936 Steel"
M2 = "M2a"
M3 = "M3a"
M4 = "M4a"

SectionType
S1 = "C 15x33.9"
S2 = "W 12x40"
S3 = "W 9x38.5"
S4 = "L 2x2x1/4"
S5 = "L 3x2x1/4"

MemberCrossSection
Rolled = R1
TopFlangePlate
36.0 1.25 M1
BottomFlangePlate
36.0 1.25 M1
Beam S2 M1
Connection Bolted 14.875

Builtup = B1
TopFlangePlate
18.0 0.5 M1
BottomFlangePlate
18.0 0.5 M1
WebPlate 26.0 0.375 M1

ChannelBox = CB1
TopFlangePlate
18.0 0.75 M1
BottomFlangePlate
18.0 0.75 M1
LeftWebPlate
15.0 1.5 M1
RightWebPlate
15.0 1.5 M1
LeftWebPlate2
1.5 8.0 M1
RightWebPlate2
1.5 8.0 M1
Channels "C 15x45" Outward 10.0
Connection Riveted 10.25
Lacing Bottom

AngleBox = AB1
TopFlangePlate
25.25 0.625 M1
BottomFlangePlate
13.25 0.625 M1
LeftWebPlate
36.0 1.125 M1
RightWebPlate
36.0 1.125 M1
LeftWebPlate2
0.625 12.875 M1
RightWebPlate2
0.625 12.875 M1
TopAngles "L 3x2x1/4" Horizontal Inward
BottomAngles "L 3x2x1/4" Horizontal Inward
BackToBack 24.75 36.0
Connection Bolted 19.125

NonDetailed = NonDetailed1
20.05 15.78 M1 154.5

Symmetry Even

PanelPoint
L0 Lower 0.0 0.0
U1 Upper 1.0 1.0
L2 Lower 2.0 0.0
U2 Upper 2.0 1.0
L3 Lower 3.0 0.0
U3 Upper 3.0 1.0
L1 Lower 1.0 0.0
U4 Upper 4.0 1.0
L4 Lower 4.0 0.0

Member
L0L1 L0 L1 CB1
L0U1 L0 U1 CB1
L1L2 L1 L2 CB1
L1U1 L1 U1 AB1
L2L3 L2 L3 "ND1"
L2U2 L2 U2 CB1
L3L4 L3 L4 "ND1"
L3U3 L3 U3 R1
L3U4 L3 U4 B1
U1L2 U1 L2 CB1
U1U2 U1 U2 AB1
U2L3 U2 L3 CB1
U2U3 U2 U3 CB1
U3L4 U3 L4 CB1
U3U4 U3 U4 CB1

MemberEccen
L0L1 100.0
L0U1 99.0
L1L2 98.0

Support
L0 Pinned
L3 Roller

PanelPointLoad
U1 DC 1.0 3.0
L4 DW 2.0 4.0

AdditionalSelfLoad 1.0 2.0

LLDistribution
OneLane 1.0 2.0
MultiLane 3.0 4.0
```

Gusset Plate Dimension Processing Using MicroStation and VBA

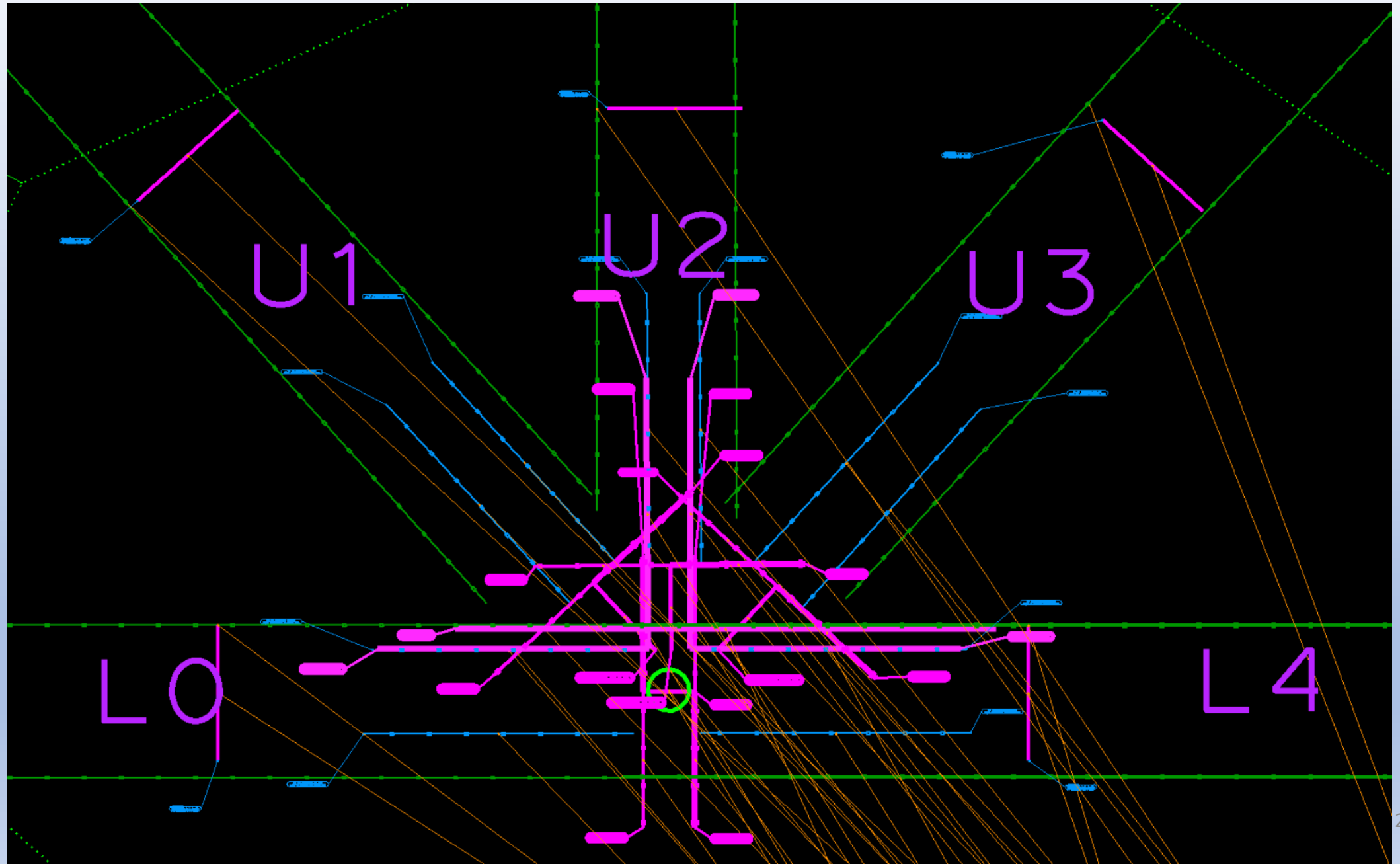
Gusset Plate Data Generation Procedures

1. Use the MicroStation template to measure the gusset plate from a scaled as-built plan or drone photo
2. Run the MicroStation macro to measure the remaining gusset plate information and write the data to the Excel file
3. Convert the gusset plate data into a format for BrDR Input
4. Transfer the gusset plate data into BrDR model file

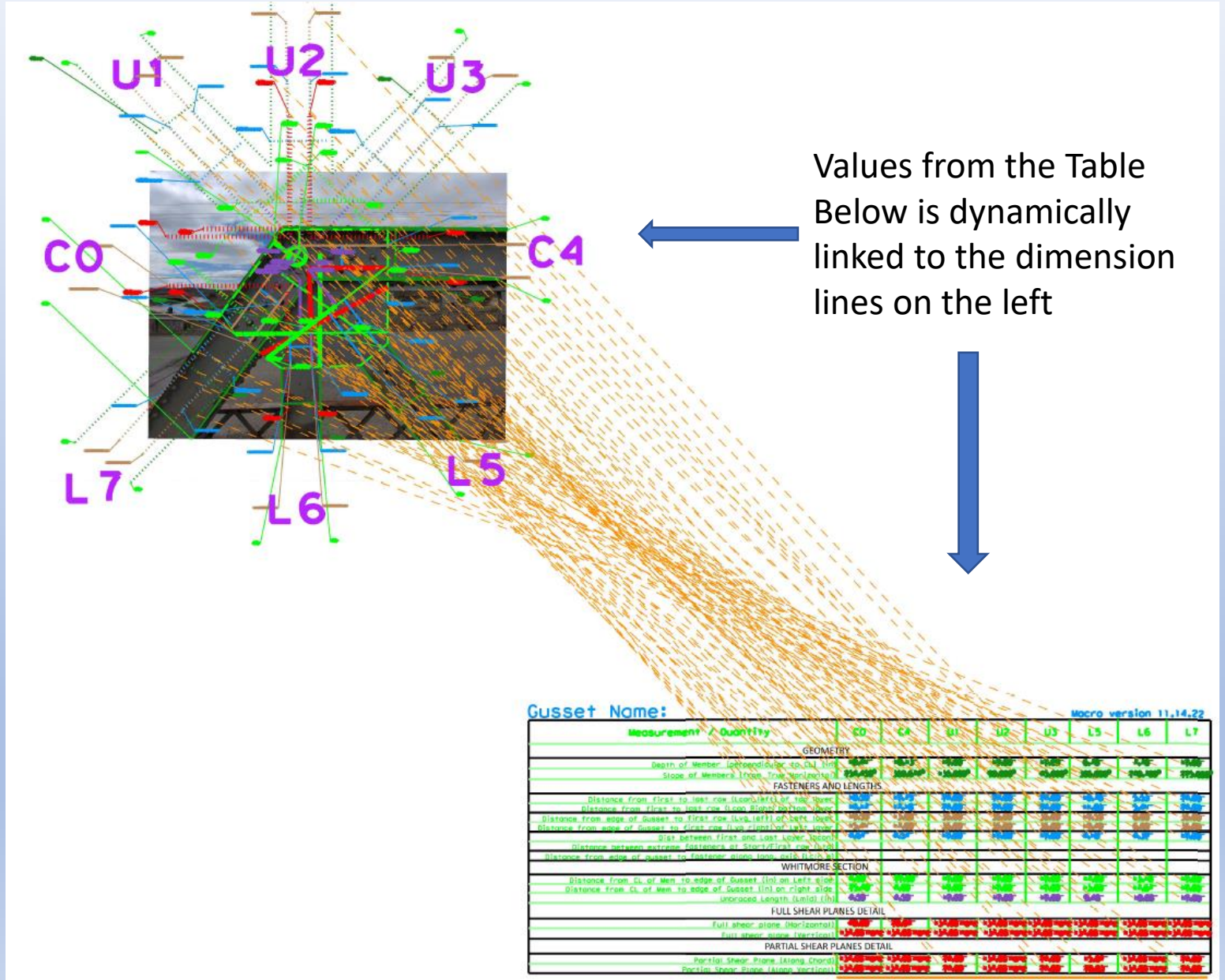
Dimensions needed for rating gusset plate



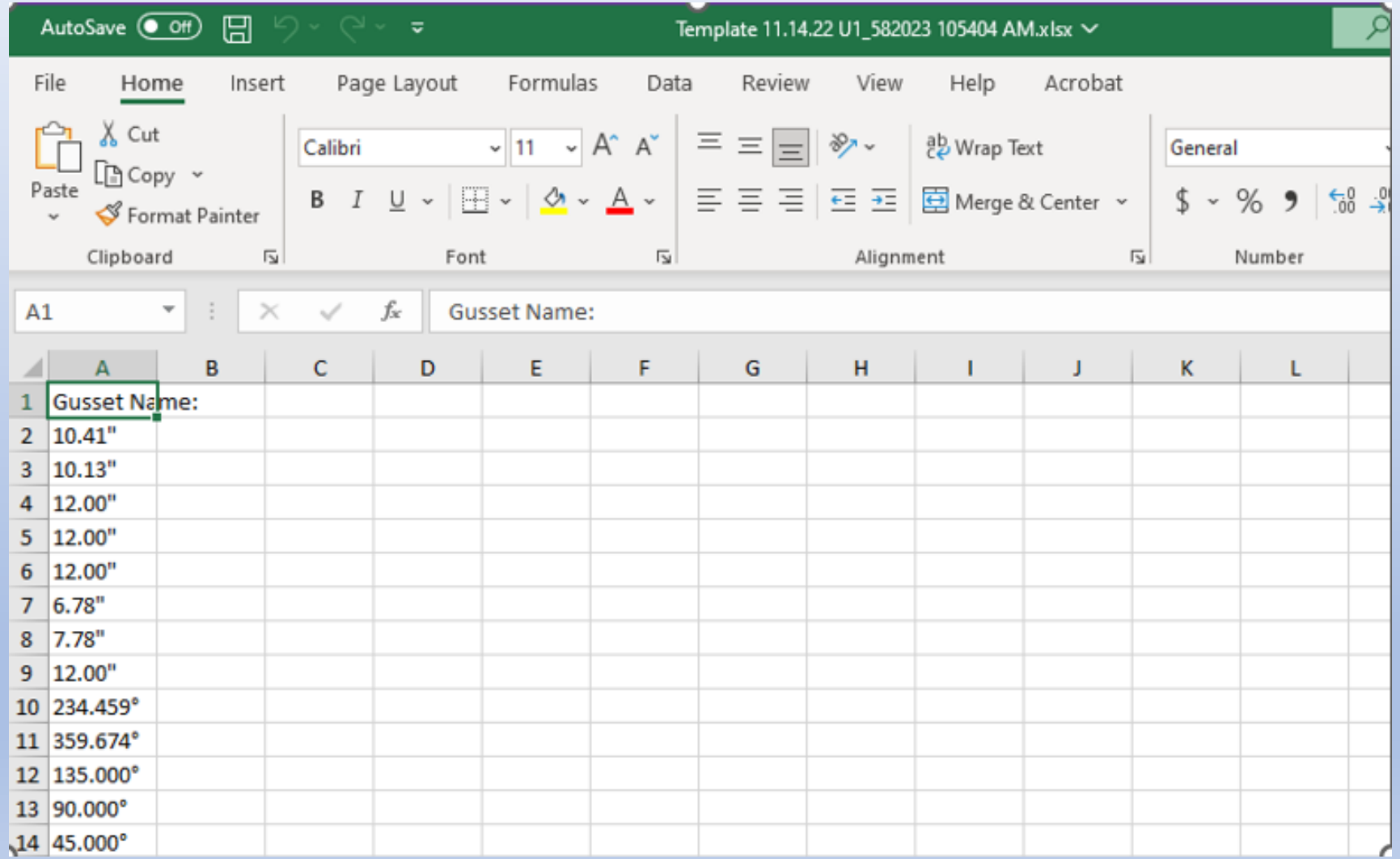
Step 1: Open A Template File and Attach Gusset Plate Details



Step 2: Adjust Lines to Match Gusset Plate Details

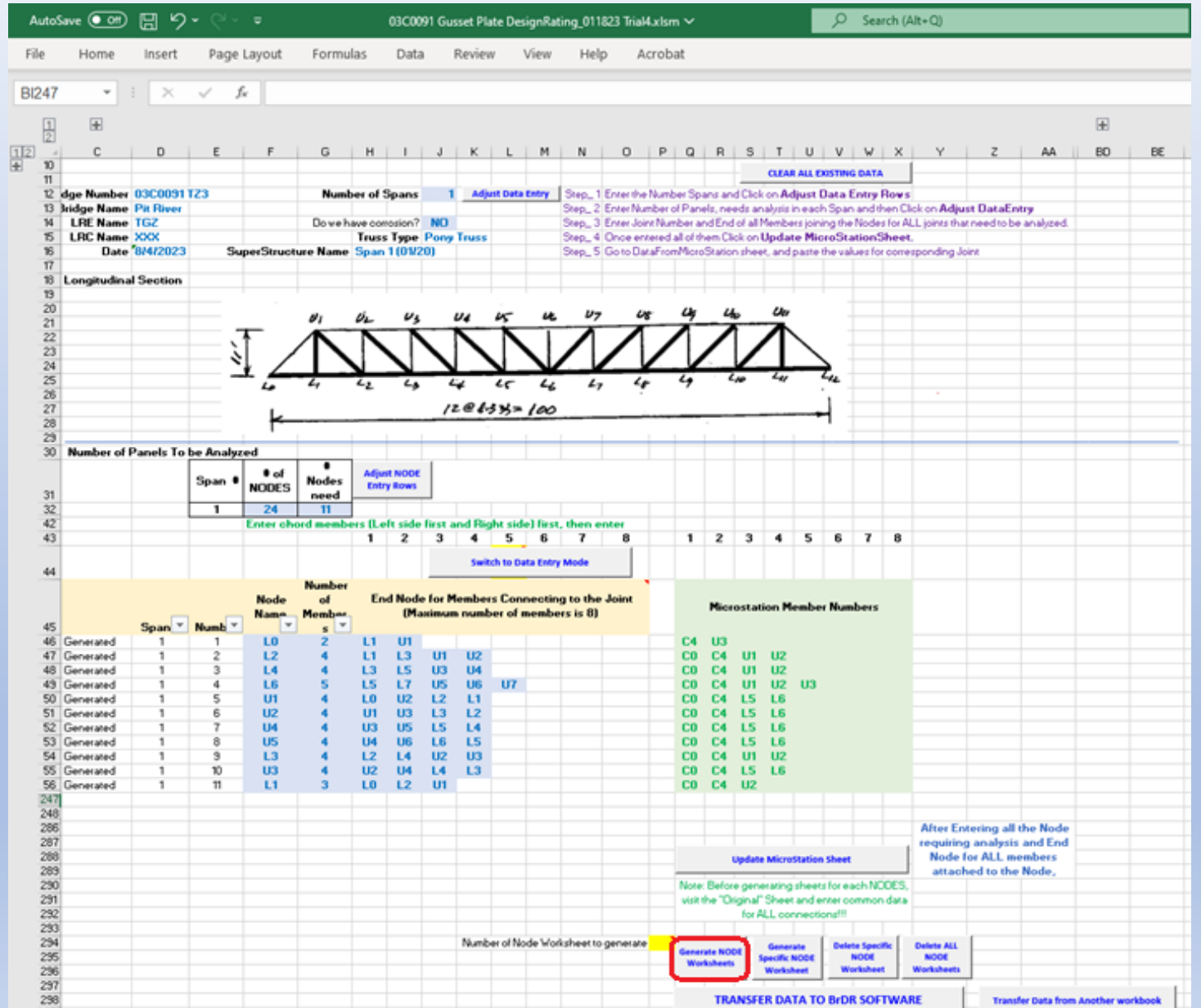


Step 3: Run Macro to Create Initial Gusset Plate Data File



	A	B	C	D	E	F	G	H	I	J	K	L
1	Gusset Name:											
2	10.41"											
3	10.13"											
4	12.00"											
5	12.00"											
6	12.00"											
7	6.78"											
8	7.78"											
9	12.00"											
10	234.459°											
11	359.674°											
12	135.000°											
13	90.000°											
14	45.000°											

Step 4: Setup Processing File, Import Initial Data and Generate Detailed Gusset Plate Data



Step 5: Add Additional Data to the Generated Sheet

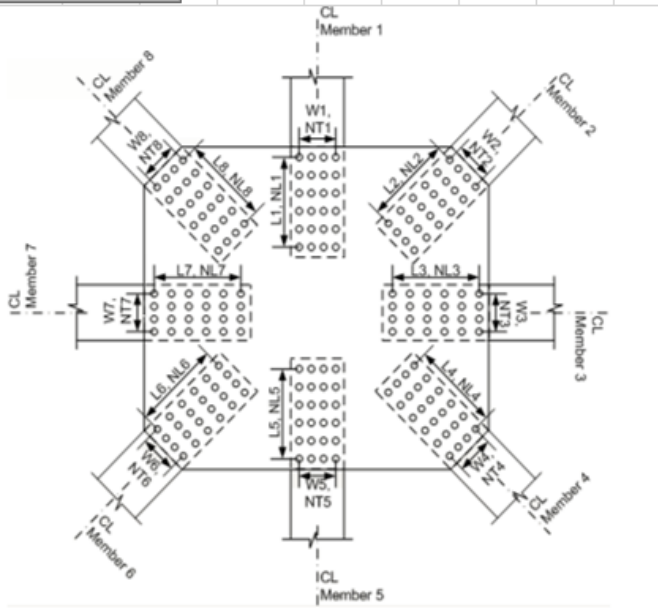
L2					
	Span Number	1			
	Number of members connected	4			
	Joints	L1	L3	U1	U2
	BrDR Member Number	7	3	8	1
	Member Name	L2-L1	L2-L3	L2-U1	L2-U2
	Type of Member	Lower Chord	Lower Chord	Diagonal	Vertical
	Microstation Member Name	C0	C4	U1	U2

Overall Gusset Plate Size and Material				
Thickness of gusset =	0.3125	in	Connector Name:	0.875 inch Rivet
Diameter of Rivets =	0.875	in	Material Name:	Fy = 30 ksi; Fu = 56 ksi
Diameter of Holes =	0.9375	in	Condition of the Gusset Plates	Good or Satisfactory
F_y Gusset =	30.0	ksi	o we have Corrsion within Gusset? (YES/NO)	NO
F_U Gusset =	56.0	ksi	Identical Gusset Plates (either side)?	YES
			Chord End Bearing?	
Overall Maximum Width (Length)	26.100	in	Chord End Bearing Percentage?	
Overall Maximum Height	29.635	in		

	Lower Chord	Lower Chord	Diagonal	Vertical
Is Chord a Continuous through the Joint?	NO	NO		
% Loads Transfer via rivets/bolts (If YES)				
% Loads transfer to Gusset Plates (if YES)				
Is there a chord splice within Gusset Plate?	NO	NO		
Depth of Member [perpendicular to CL] (in)	10.530	10.240	7.820	8.640
Slope of Members (from True Horizontal)	180.00	0.00	127.00	90.00

Fasteners and Lengths	L1	L3	U1	U2
Total (N_{fast})	9	5	10	12
Number of rivets Along Left edge	3	2	5	6
Number of Rivet holes for shear (N_{vn}) along Left edge	2.5	1.5	4.5	5.5
Distance from first to last row (L_{con_left}) of Left layer	12.090	5.590	10.670	14.860
istance from edge of Gusset to first row (L_{vg_left}) of Left layer	13.500	6.940	12.230	16.320
Number of rivets Along right edge	3	2	5	6
Number of Rivet holes for shear (N_{vn}) along right edge	2.50	1.50	4.50	5.50
Distance from first to last row (L_{con_right}) of Right layer	12.180	5.490	10.600	15.070
)istance from edge of Gusset to first row (L_{vg_Right}) right layer	13.520	6.750	12.140	16.510
Total shear plane length (L_{vg})	27.020	13.690	24.370	32.830
Total number of rivet holes (N_{vn})	5.00	3.00	9.00	11.00
Distance from first to last row (L_{con})	12.180	5.590	10.670	15.070
Number of End row Fasteners ($N_{fast,end}$)	2	2	2	2
Dist between first and Last Layer (b_{con})	4.920	4.870	4.630	4.720
Number of first row Fasteners (N_{whit})	2	2	2	2
Distance between extreme fasteners at Start/First row (L_{lg})	7.725	7.555	4.630	4.720
Number of Rivet holes for tension (N_{tn})	2	2	2	2
tance from edge of gusset to fastener along long. axis (L_{clr_e})	1.500	1.500	1.500	1.500
Length Perpendicular to Member at first row (for Whitmore Section)				
Distance from CL of Mem to edge of Gusset (in) on Left side	24.610	5.000	16.350	6.400
istance from CL of Mem to edge of Gusset (in) on Right side	4.980	24.680	13.210	19.330

Reset the data entry fields



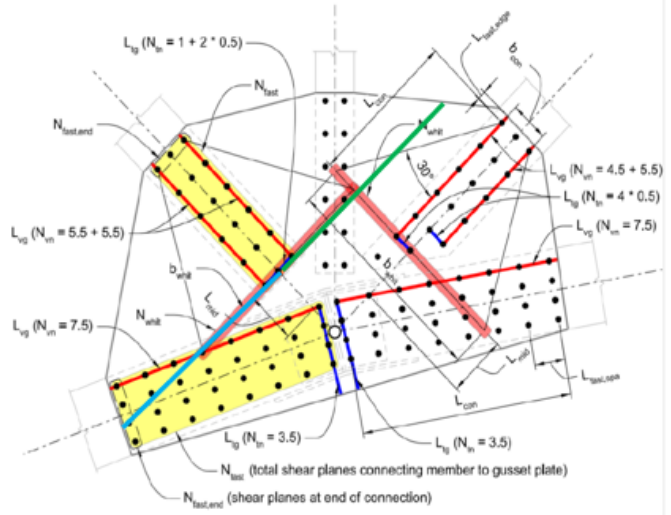


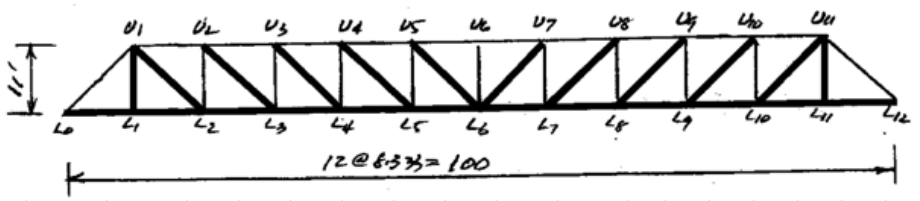
Figure 13 - Member Connection Variables

Step 6: Transfer Gusset Plate Data into BrDR Model

CLEAR ALL EXISTING DATA

dge Number	03C0091 TZ3	Number of Spans	1	Adjust Data Entry	Step_1 Enter the Number Spans and Click on **Adjust Data Entry Rows**
Bridge Name	Pit River				Step_2 Enter Number of Panels, needs analysis in each Span and then Click on **Adjust DataEntry**
LRE Name	TGZ	Do we have corrosion?	NO		Step_3 Enter Joint Number and End of all Members joining the Nodes for ALL joints that need to be analyzed.
LRC Name	XXX	Truss Type	Pony Truss		Step_4 Once entered all of them Click on **Update MicroStationSheet.**
Date	8/4/2023	SuperStructure Name	Span 1 (01/20)		Step_5 Go to DataFromMicroStation sheet, and paste the values for corresponding Joint

Longitudinal Section



Number of Panels To be Analyzed

Span #	# of NODES	# Nodes need
1	24	11

Adjust NODE Entry Rows

Enter chord members (Left side first and Right side) first, then enter

1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8

Switch to Data Entry Mode

	Span	Numb	Node Name	Number of Members	End Node for Members Connecting to the Joint (Maximum number of members is 8)								Microstation Member Numbers							
Generated	1	1	L0	2	L1	U1							C4	U3						
Generated	1	2	L2	4	L1	L3	U1	U2					C0	C4	U1	U2				
Generated	1	3	L4	4	L3	L5	U3	U4					C0	C4	U1	U2				
Generated	1	4	L6	5	L5	L7	U5	U6	U7				C0	C4	U1	U2	U3			
Generated	1	5	U1	4	L0	U2	L2	L1					C0	C4	L5	L6				
Generated	1	6	U2	4	U1	U3	L3	L2					C0	C4	L5	L6				
Generated	1	7	U4	4	U3	U5	L5	L4					C0	C4	L5	L6				
Generated	1	8	U5	4	U4	U6	L6	L5					C0	C4	L5	L6				
Generated	1	9	L3	4	L2	L4	U2	U3					C0	C4	U1	U2				
Generated	1	10	U3	4	U2	U4	L4	L3					C0	C4	L5	L6				
Generated	1	11	L1	3	L0	L2	U1						C0	C4	U2					

Update MicroStation Sheet

After Entering all the Node requiring analysis and End Node for ALL members attached to the Node,

Note: Before generating sheets for each NODES, visit the "Original" Sheet and enter common data for ALL connections!!!

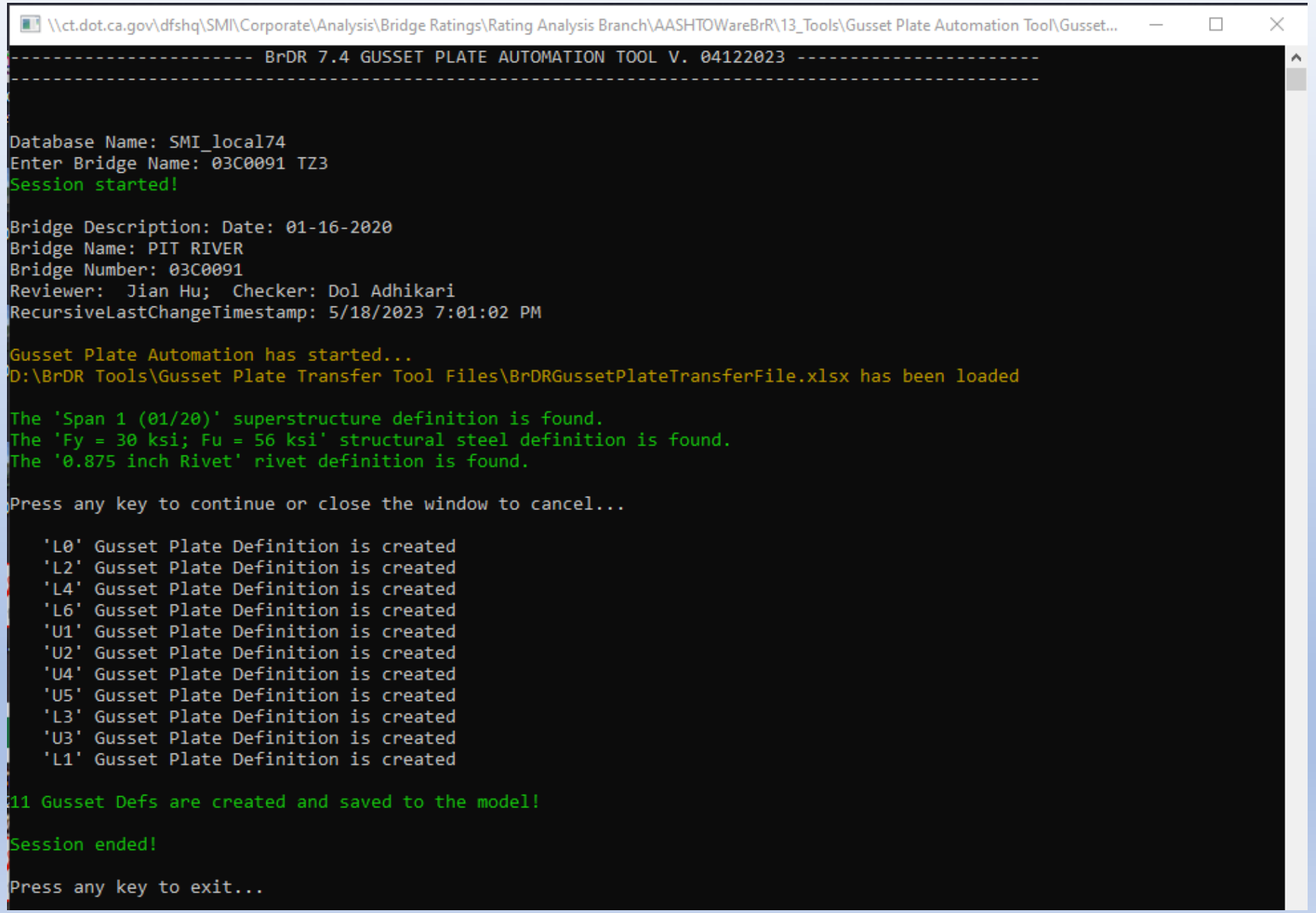
Number of Node Worksheet to generate

Generate NODE Worksheets | Generate Specific NODE Worksheet | Delete Specific NODE Worksheet | Delete ALL NODE Worksheets

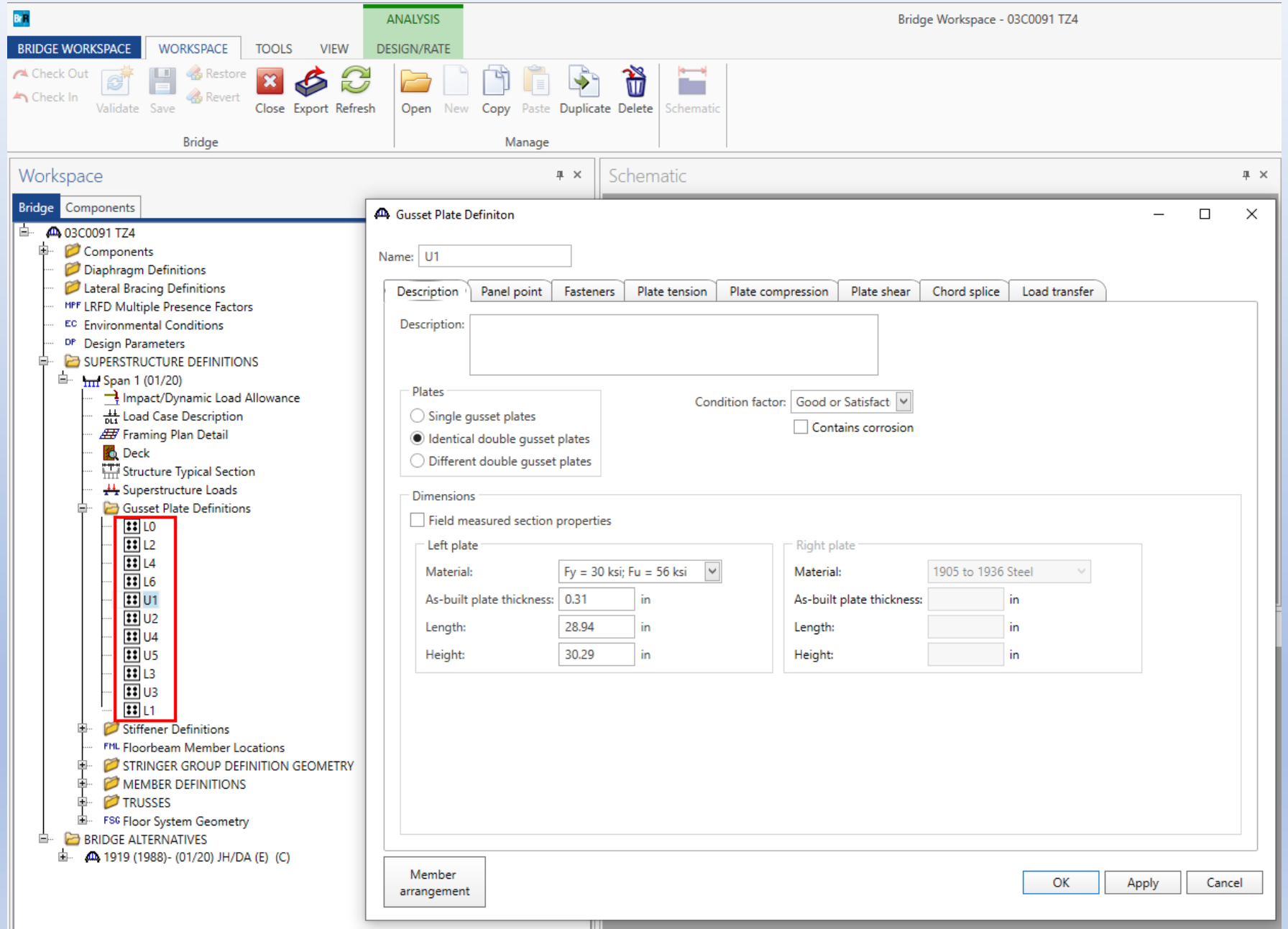
TRANSFER DATA TO BrDR SOFTWARE

Transfer Data from Another workbook

Transfer Gusset Plate Data to BrDR Model with VBA Macro



New Gusset Plate Data Added in Existing BrDR Model



Discussion

- Accuracy of Drone Photos
- Corrosion and Deterioration
- LFR vs LRFR for truss bridge rating
- Rivet Size and Material Designation
- Enhancements recommended for Truss/Gusset Plate Rating

Enhancement for Truss and Gusset Plate

Gusset Plate:

- BSSD-2794 (HNTB): BrDR Gusset Module: Comments on the treatment of continuous chords (the item same as BSSD-4091)
- BSSD-3849 (Caltrans): Include splice plates when rating gusset plate chord splices, if any
- BSSD-1826(Baker): Check connector's bearing and block shear capacity on all the connected truss members when rating gusset plates.

Truss:

- BSSD-1810(Billy Metcalf): Spec check for AASHTO BDS Article 6.8.2 does not use the user-defined shear lag factor U

Thanks!

Questions?