CT's Approach to LRFR Truss Analysis

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Bridge Design
CTDOT

Contents

- Emergency Vehicle Rating with Adjacent Vehicles
- Issues & Limitations
- Workarounds

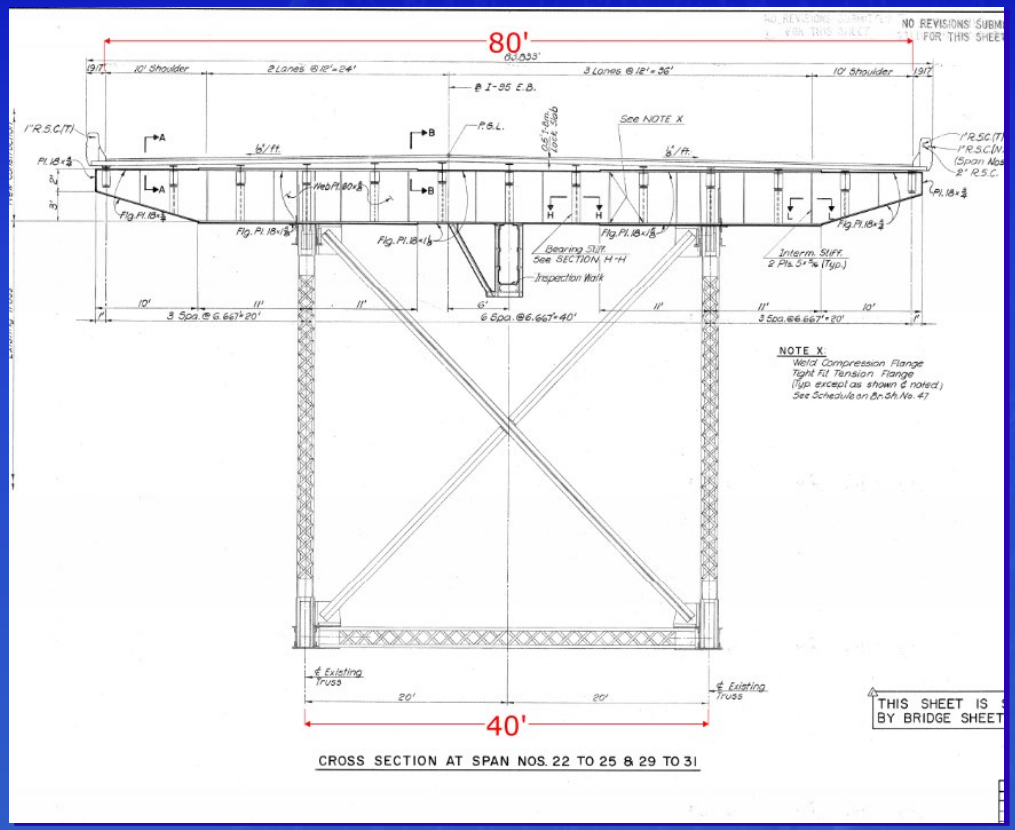
CT's Rating Standards

- Evaluation Method: LRFR
- Check all limit states
- 23 Vehicles
  - Design Vehicles
  - 7 AASHTO Legal
  - 4 State Legal
  - 9 Permits
  - 2 Emergency

Rating Software

- Primary Rating Tool: BrR
- Cannot be rated in BrR
  - Can input be modified to achieve an accurate rating
  - Can results be taken from BrR?
    - Strengthening Cover Plates
    - Removal of in-span hinges
    - Bug Workarounds
- Use other general finite element software

Adjacent Vehicles

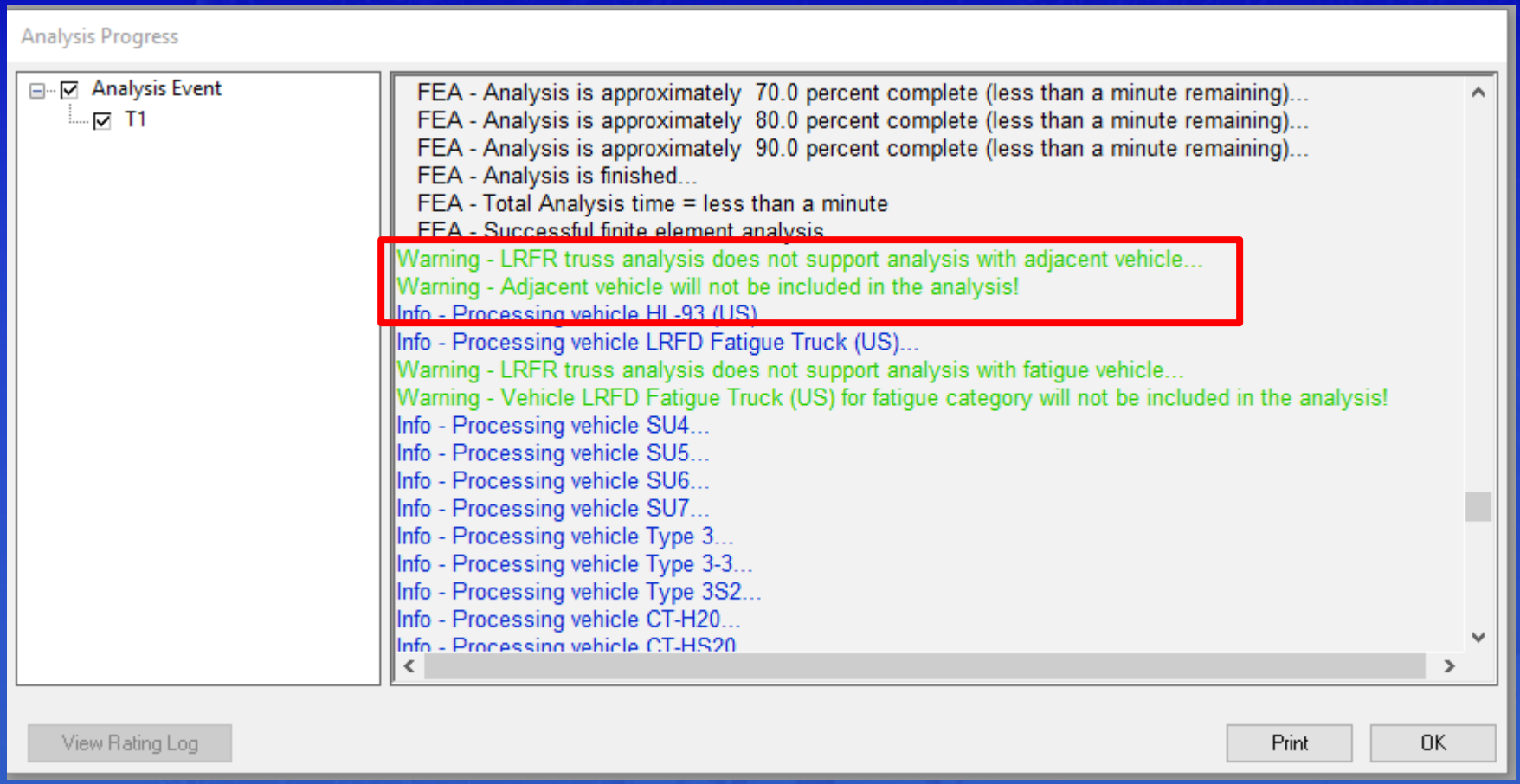


- Trusses with large overhangs
- Emergency vehicles placed along curb lines

"Multiple presence: If necessary, when combined with other unrestricted legal loads for rating purposes, the emergency vehicle needs only to be considered in a single lane of one direction of a bridge."

– FHWA Load Rating For the FAST ACT's Emergency Vehicles

Adjacent Vehicles



BRDSUP-1302: Adding adjacent vehicle option for LRFR legal rating

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How Do We Do It?

BrR

- Model the Superstructure
- Run the LRFR Analysis

Excel

- Import the Member Forces
- Perform the Rating

Comments for the RADBUG 2019 *CT's Approach to LRFR Truss Analysis* presentation

Slide 15:
BSSD-356 has been resolved for the 6.8.4 release and the upcoming 7.0 release.

Slide 19:
Enhancement request: Variable depth trusses (BSSD-2370 Define custom shear plane orientation for gusset plate analysis).

BrR Force Output Reports

- XML Based Output Reports
- 2 Report Types
  1. Panel Point Max Forces
     - Member Loads
     - Gusset Plate DL Forces
  2. Panel Point Concurrent Forces
     - Gusset Plate Live Load Forces

Panel Point Max Forces

Truss Panel Point Maximum Forces

Bridge Name: -1
NBI Structure ID: 04621
Bridge ID: 04621

Analyzed By: patriacm
Analyze Date: Tuesday, July 09, 2019 13:40:52
Analysis Engine: AASHTO Truss LRFR Engine Version 6.8.3.3001

Report By: patriacm
Report Date: Tuesday, July 09, 2019 13:40:57
Report Stylesheet: C:\ProgramData\AASHTOWARE\BrDR683\Xsl Files\TrussPanelPointMaxForces.xslt

Superstructure Definition Name: Span 01
Truss Name: T1

Note:
- Theta is measured from the positive longitudinal axis in counterclockwise direction.
- Impact and distribution factors are included in live load forces.
- Positive member force indicates member in tension. Negative member force indicates member in compression.
- Positive net force indicates force is acting in positive direction. Negative net force indicates force is acting in negative direction.

LL Codes:
- (T) Truck load controls
- (L) Lane load controls
- (Tn) Tandem load controls
- (TP) Truck Pair load controls
- (LgP) Legal pair load controls
- (TnT) Tandem Train load controls
- (T+L) Truck + Lane load controls
- (Tn+L) Tandem + Lane load controls
- (TP+L) Truck Pair + Lane load controls
- (LgP+L) Legal Pair + Lane load controls
- (TnT+L) Tandem Train + Lane load controls

Live Load: CT-P120(6) (Permit Truck)
As Requested Impact: With Impact
As Request Lane: Multi-Lane
LL Scale Factor: 1.00

Panel Point (ft)	Member	Theta (Degrees)	DC Force (kip)	DW Force (kip)	LL Force (kip) Compression	LL Force (kip) Tension	
L0 [0.00, 0.00]	L0L1	0.00	56.77	9.25		64.27 (T)	
	L0U1	60.89	-116.70	-19.02	-132.11 (T)		
	Net Longitudinal Force:		0.00	0.00	0.00		
	Net Vertical Force:		101.96	16.61	115.42		
	L0U1	240.89	-116.70	-19.02	-132.11 (T)		

Truss Panel Point Concurrent Forces

Bridge Name: -1
NBI Structure ID: 04621
Bridge ID: 04621

Analyzed By: patriacm
Analyze Date: Tuesday, July 09, 2019 13:40:52
Analysis Engine: AASHTO Truss LRFR Engine Version 6.8.3.3001

Report By: patriacm
Report Date: Tuesday, July 09, 2019 13:40:57
Report Stylesheet: C:\ProgramData\AASHTOWARE\BrDR683\Xsl Files\TrussPanelPointConcurrentForces.xslt

Superstructure Definition Name: Span 01
Truss Name: T1

Note:
- Theta is measured from the positive longitudinal axis in counterclockwise direction.
- Impact and distribution factors are not included in live load forces.
- Positive member force indicates member in tension. Negative member force indicates member in compression.
- Concurrent forces are based on the first truck position that causes the critical force in the primary member.

LL Codes:
- (T) Truck load controls
- (L) Lane load controls

Panel Point (ft)	Primary Member (Degrees)	Corresponding Member	Critical LL Force (kip) Compression	Concurrent LL Force (kip) Compression / Tension	Critical LL Force (kip) Tension	Concurrent LL Force (kip) Compression / Tension
L0 [0.00, 0.00]	L0L1 [0.00]				60.13 CT-P120(6) - Permit Truck	
		L0U1				-92.93
	L0U1		-123.60			

- Reports the Max and Minimum forces for each member
- Impact and distribution factors are included

- Reports the concurrent load
- Impact and distribution factors are not included
- Run one vehicle at a time. BrR combines all vehicles used in the analysis

Truss Force XML Output

Import Forces XML into Excel

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="C:\ProgramData\AASHTOWare\BrDR683\Xsl Files\TrussPanelPointConcu
<Panel_Point_Concurrent_Forces_Report>
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    <Bridge_Name>-1</Bridge_Name>
    <NBI_Structure_ID>04621</NBI_Structure_ID>
    <Bridge_ID>04621</Bridge_ID>
    <Analyze_By>patriacm</Analyze_By>
    <Analyze_Date>Tuesday, July 9, 2019</Analyze_Date>
    <Analysis_Engine>AASHTO Truss LRFR Engine Version 7.0.0.0</Analysis_Engine>
    <Report_By>patriacm</Report_By>
    <Report_Date>7/9/2019</Report_Date>
    <Report_Stylesheet>C:\ProgramData\AASHTOWare\BrDR683\Xsl Files\TrussPanelPointConcurrentForces.xsl
    <StructDef_Name>Span 01</StructDef_Name>
    <Member_Name>T1</Member_Name>
</Report_Header>
<Concurrent_Forces>
    <Concurrent_Forces_Table>
        <Concurrent_Forces_Table_Header>
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            <Force_Unit>kip</Force_Unit>
        </Concurrent_Forces_Table_Header>
        <Panel_Point>
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<![CDATA[L0]]>
            </Name>
            <Longitudinal_Coordinate Unit="ft">0.00</Longitudinal_Coordinate>
            <Vertical_Coordinate Unit="ft">0.00</Vertical_Coordinate>
            <Primary_Member>
                <Name>
<![CDATA[L0L1]]>
                </Name>
                <Theta>0.00</Theta>
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<![CDATA[]]>
                </Critical_Compression_Live_Load>
                <Critical_Tension_Live_Load>
<![CDATA[CT-P120(6) - Permit Truck]]>
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                <Member>
                    <Name>
<![CDATA[L0L1]]>
                    </Name>
                    <Compression_LL_Force></Compression_LL_Force>
                    <Tension_LL_Force>60.13</Tension_LL_Force>
                </Member>
                <Member>
                    <Name>
```

Live Load Case Name	Element	at Node	Axial Force (kips)	Adjacent Vehicle (kips)
minCT-P120(6) - Permit Truck"T"_Node1_Elemfx2	2	1	-123.60	-61.8
maxCT-P120(6) - Permit Truck"T"_Node1_Elemfx2	2	1	0.00	0
minCT-P120(6) - Permit Truck"T"_Node1_Elemfx2	1	1	45.21	22.605
maxCT-P120(6) - Permit Truck"T"_Node1_Elemfx2	1	1	0.00	0
minCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	2	2	-123.60	-61.8
maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	2	2	0.00	0
minCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	3	2	-90.42	-45.21
maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	3	2	0.00	0
minCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	4	2	92.93	46.465
maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	4	2	0.00	0
minCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	3	2	-120.26	-60.13
maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	3	2	0.00	0
minCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	2	2	-92.93	-46.465
maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	2	2	0.00	0
minCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	4	2	92.93	46.465
maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	4	2	0.00	0
minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	6	3	-100.77	-50.385
maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	6	3	8.07	4.035
minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	1	3	36.86	18.43
maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	1	3	20.67	10.335
minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	5	3	110.57	55.285
maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	5	3	38.39	19.195
minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	4	3	75.76	37.88
maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	4	3	42.49	21.245
minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	7	3	0.00	0
maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	7	3	0.00	0
minCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	3	4	-120.26	-60.13
maxCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	3	4	0.00	0
minCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	8	4	-90.42	-45.21
maxCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	8	4	0.00	0
minCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	7	4	0.00	0
maxCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	7	4	0.00	0
minCT-P120(6) - Permit Truck"T"_Node4_Elemfx8	8	4	-120.26	-60.13

XML **Excel**

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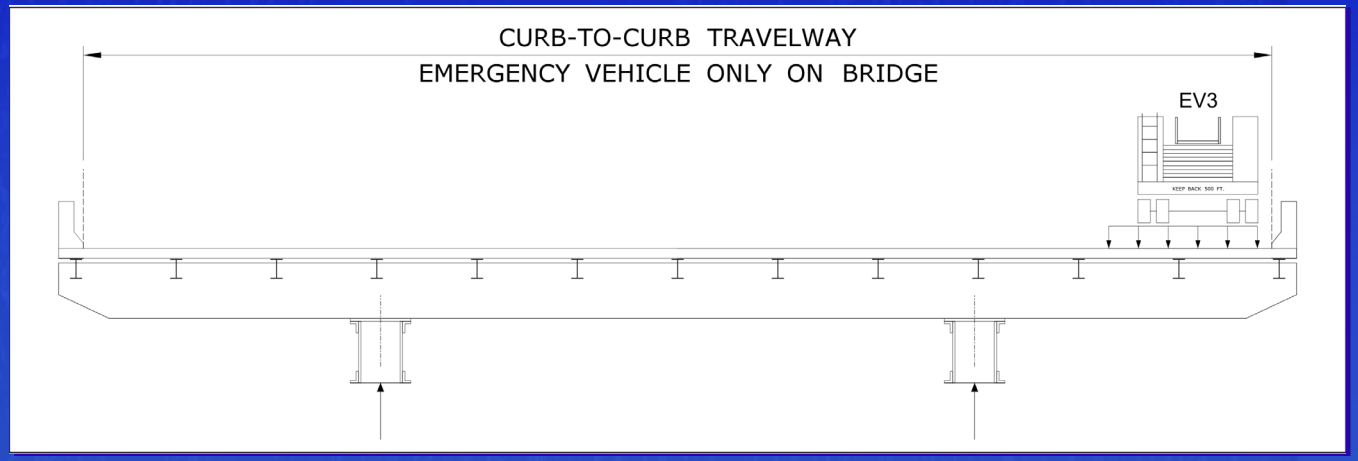
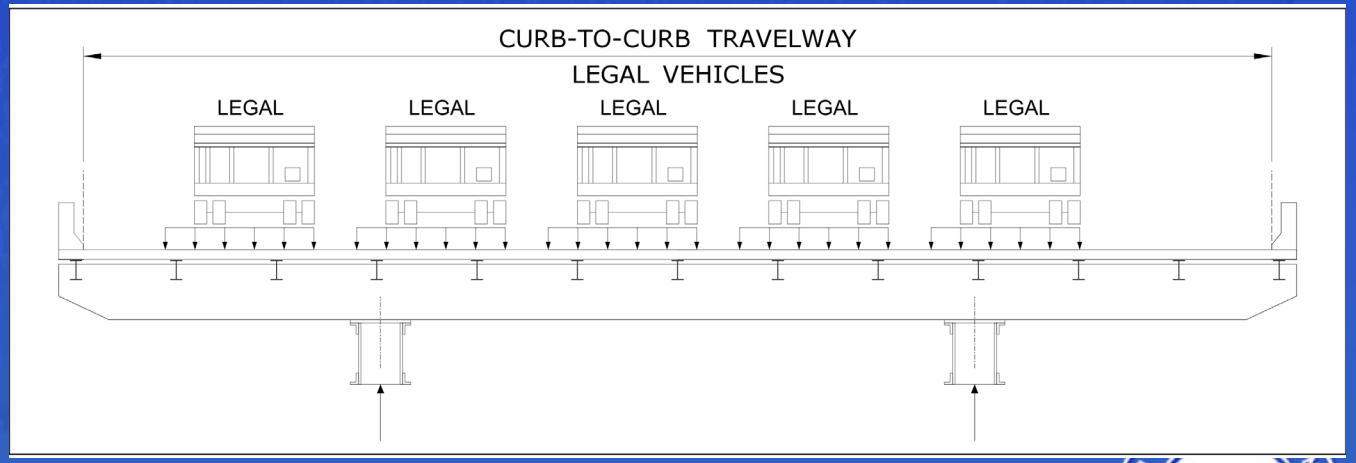
Superimposing Loads

Compute EV D.F.



Compute Adjacent Lane Legal D.F.



Carry Out Rating

$$RF = \frac{C - DL - AL}{LL}$$

Notes:

- **Apply distribution factors, impact when Concurrent Truss Forces are used**
- **Similar process for Special Permits Mixed with Traffic**

Fatigue Ratings

- No Fatigue Analysis in BrR
- Fatigue Vehicle Forces are Extracted from BrR and rated externally
- Example: Material around rivets & Misc. welded attachments

Block Shear

- BRDRSUP-1866
- No User override for A_{vn}, A_{vg}, & A_{tn} for other failure paths
- Tension Capacity Override Required

Minimum Load Factors

- **BrR uses a minimum load factor of 1.0.**

- **Workarounds:**
  - **Use BrR Forces and Rate via spreadsheets.**
  - **Determine that Stress Reversal is not critical**

Load	Load Combo	Limit State	Axial LL (kip)	DC	DW	LL	PhiPn (kip)	Ovrride Phi	Ovrride Pn(kip)	RF	Capacity (Ton)	Note
DesignInv	14	STR-I	92.84	1.25	1.50	1.75	317.44			1.61	58.02	
DesignInv	14	STR-I	-72.60	1.00	1.00	1.75	-225.30			2.12	76.21	
DesignOp	14	STR-I	92.84	1.25	1.50	1.35	317.44			2.09	75.22	
DesignOp	14	STR-I	-72.60	1.00	1.00	1.35	-225.30			2.74	98.79	
DesignInv	15	STR-I	76.95	1.25	1.50	1.75	317.44			1.94	48.62	
DesignInv	15	STR-I	-60.92	1.00	1.00	1.75	-225.30			2.52	63.07	
DesignOp	15	STR-I	76.95	1.25	1.50	1.35	317.44			2.52	63.02	
DesignOp	15	STR-I	-60.92	1.00	1.00	1.35	-225.30			3.27	81.76	
LegalRoutine	20	STR-I	51.36	1.25	1.50	1.30	317.44			3.92	98.05	
LegalRoutine	20	STR-I	-41.78	1.00	1.00	1.30	-225.30			4.95	123.78	

Half Through-Trusses

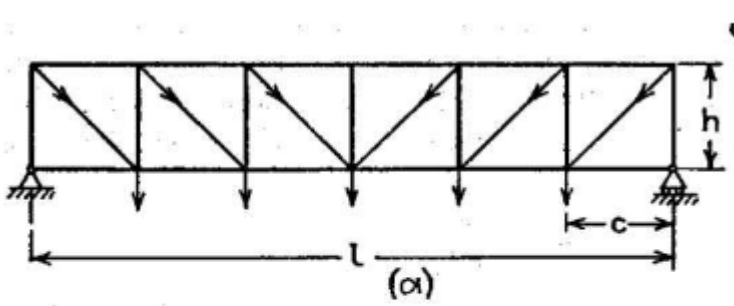


FIG. 2-42

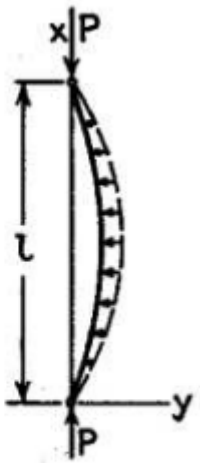
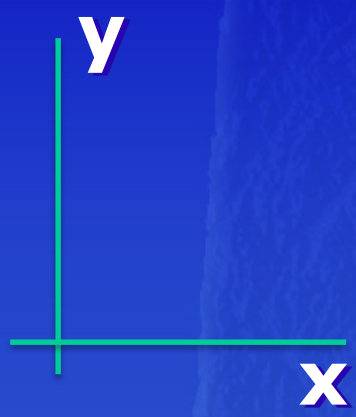
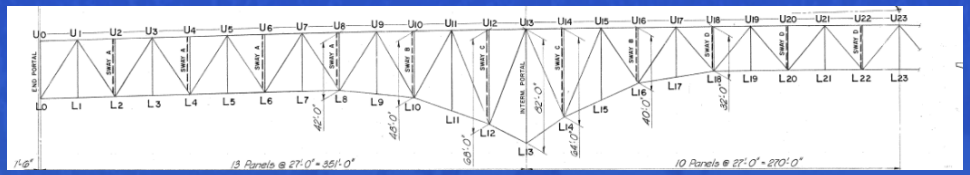


FIG. 2-37

- **Top Chord is elastically braced.**
  MBE C6A.6.9.1 & BDS 6.14.2.9
- **Elastically braced Top Chords are not considered in BrR.**
- **Capacity Overrides or Rate externally**

Variable Depth Trusses



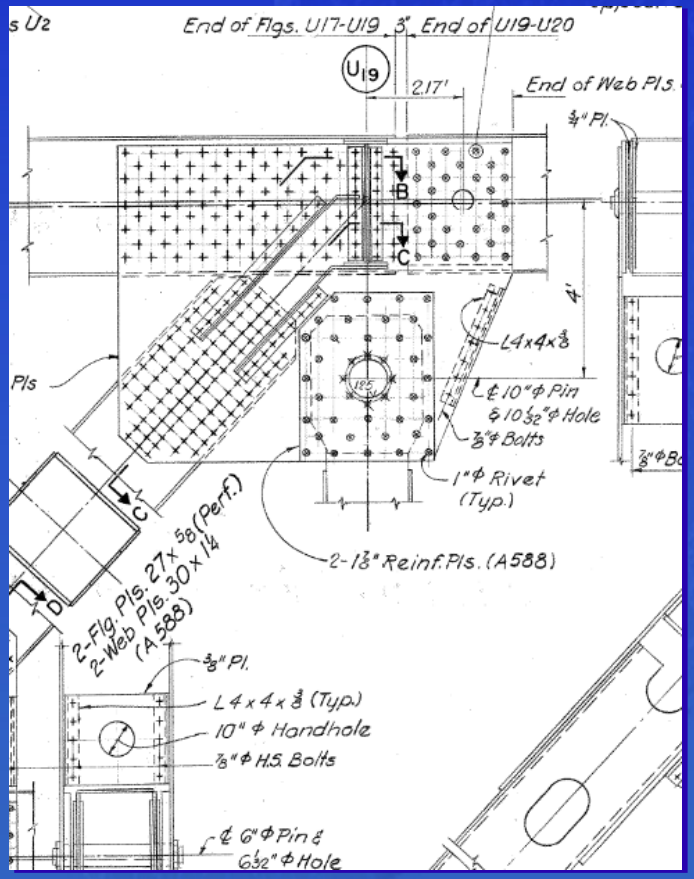


Gusset Plates Cannot be rated in BrR

Pin Connected Members

Pins Connecting One Member:

Use Capacity override



$$M = \frac{P*L}{4}, \qquad V = \frac{P}{2}$$

$$\frac{6.0 * M}{\varphi_f \varphi_{cs} * D^3 * F_y} + \left(\frac{2.2 * V}{\varphi_v \varphi_{cs} * D^2 * F_y} \right)^3 = 0.95$$

$$\frac{6.0 * \frac{P * L}{4}}{\varphi_f \varphi_{cs} * D^3 * F_y} + \left(\frac{2.2 * \frac{P}{2}}{\varphi_v \varphi_{cs} * D^2 * F_y} \right)^3 = 0.95$$

Solve for P

Pin Connected Members

Pins Connecting Multiple Members:

Rate Outside of BrR

Summary

- Adjacent Vehicle Rating
- Fatigue Rating
- Block Shear
- Half-Through Trusses
- Minimum Load Factors
- Variable Depth Trusses
- Pin Connected Members

Questions

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