<u>CT's Approach to LRFR Truss</u> <u>Analysis</u>

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Bridge Design CTDOT



<u>Contents</u>

 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



<u>Rating Software</u>

- 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

Analysis Progress

⊡… ☑ Analysis Event	FEA - Analysis is approximately 70.0 percent complete (less than a minute remaining) FEA - Analysis is approximately 80.0 percent complete (less than a minute remaining) FEA - Analysis is approximately 90.0 percent complete (less than a minute remaining) FEA - Analysis is finished FEA - Total Analysis time = less than a minute EEA - Successful finite element analysis							
	Warning - LRFR truss analysis does not support analysis with adjacent vehicle Warning - Adjacent vehicle will not be included in the analysis! Info - Processing vehicle HI -93 (US)							
	Info - Processing vehicle LRFD Fatigue Truck (US) Warning - LRFR truss analysis does not support analysis with fatigue vehicle Warning - Vehicle LRFD Fatigue Truck (US) for fatigue category will not be included in the analysis! Info - Processing vehicle SU4 Info - Processing vehicle SU5 Info - Processing vehicle SU5 Info - Processing vehicle SU5							
	Info - Processing vehicle Type 3 Info - Processing vehicle Type 3-3 Info - Processing vehicle Type 3S2 Info - Processing vehicle CT-H20 Info - Processing vehicle CT-HS20	>						
View Rating Log	Print	ОК						

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



How Do We Do It?

Model the Superstructure

• Run the LRFR Analysis

- Import the Member Forces
- Perform the Rating

BrR



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

Truss Panel Point Concurrent Forces

Sridge Name: NBI Structure ID:		-1 04621																	
Bridge ID:		04621							S. 84		Bridge Nam	ne:	-1						
Analyzed By:		patriacm							15.2 E +		NBI Structu	ure ID:	04621						
Analyze Date: Analysis Engine:		Tuesday, . AASHTO	uly 09, 201 Truss LRFI	9 13:40:52 R Engine Ve	ersion 6.8.3.	3001			- 1.16G		Bridge ID:		04621						
Peneut Pro		entricom																	
Report Date:		Tuesday, 1	uly 09, 201	9 13:40:57							Analyzed B	iy:	patriacm	Tute 00 2010 12-40-52					
Report Stylesheet:		C:\Progra	nData\AAS	HTOWARI	E\BrDR683\	Xsl Files\TrussPanel	PointMaxForce:	s.xslt	8 2 G A 1		Analyze Da Analysis En	ngine:	AASHTC) Truss LRFR Engine V	Version 6.8.3 3001				
Superstructure De	finition Name	e: Span 01							1997			-g		, most branching inc.					
ti uss ivanie.									Sec. 1		Report By:		patriacm						
Note:											Report Date	e:	Tuesday,	July 09, 2019 13:40:57					
Impact and distri Positive member	d from the po- bution factors force indicate	sitive longit are include es member i	f in live loa tension. N	n countercio d forces. egative men	nber force in	ection. idicates member in c	ompression.			Report Stylesheet: C:\Program		mData\AASHTOWAR	E\BrDR683\Xsl Files\?	FrussPanelPointCon	currentForces.xslt				
Positive net force	e indicates for	ce is acting	n positive d	irection. Ne	gative net fo	orce indicates force is	acting in negat	tive direction.	5 pt - 2		Superstruct	ture Definition	Name: Span 01						
(T) Truck load co	ontrols										Truss Name	e:	T1						
(L) Lane load con (Tn) Tandem load (TP) Truck Pair 1 (LgP) Legal pair (TnT) Tandem Tr	ntrols d controls load controls load controls rain load contr	rols							a d	1	Note:								
(T+L) Truck + L: (Tn+L) Tandem	ane load contr + Lane load co	ontrols							1.1	137021	Theta is measured from the positive longitudinal axis in counterclockwise direction.								
(TP+L) Truck Pa (LgP+L) Legal P	ir + Lane load air + Lane loa	d controls ad controls							1.54		 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 								
(InT+L) Tanden	i Train + Lane	e load contro	ls						3.87	1. A. H.	 Concurre 	ent forces are ba	used on the first tru	ick position that causes	the critical force in the	primary member.			
Live Load: As Requested Impac As Request Lane: LL Scale Factor:	CT-P120 ct: With Impac Multi-Lane 1.00	(6) (Perm ct	it Truck)								LL Codes: • (T) Truck • (L) Lane	k load controls load controls							
P	anel Point (ft)	Member	Theta (Degrees)	DC Force (kip)	e DW Force (kip)	e LL Force (ki Compression Te)) nsion		Ster S			1	1						
		L0L1	0.00	56.77	9.25	5 64	.27 (T)	¥ 5	$O \otimes \mathbb{R}^{n}$		Panel	Primary	Corresponding	Critical LL Force (kip)	Concurrent LL Force (kip)	Critical LL Force (kip)	Concurrent LL Force (kip)		
	L0	L0U1	60.89	-116.70	-19.02	2 -132.11 (T)			-875	$\{0\}_{i\in \mathbb{N}}$	Point (ft)	Member (Degrees)	Member	Compression	Compression / Tension	Tension	Compression / Tension		
10		vet Longitu	linal Force	0.00	0.00	0.00			1.1.1			L0L1				60.13			
	N	Net Vertical	Force:	101.96	16.61	115.42			$s > c_{2}$		LO	[0.00]	L0U1			CT-P120(6) - Permit Truck	-92.93		
		L0U1	240.89	-116.70	-19.02	2 -132.11 (T)		Y			[0.00,	L0U1]	-123.60					
R	ep	0	ts	5 t	:h	e M	ах	and	143	•	Re	ports	s the c	concurr	ent load	1			
M m	ini er	im nt	iu De	m r	f f	orc	es	for e	each	•	Im no Ru	pact t incl	and d uded e vehi	listribu	tion fac	tors ar BrR	e connect/		

analysis

Impact and distribution 0 factors are included

Connecticut Department of Transportation

combines all vehicles used in the

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Truss Force XML Output

Import Forces XML into Excel

1	<pre><?xml version="1.0" encoding="UTF-8"?></pre>					
2	<pre>Crxml-stylesheet type="text/xsl" href="C:\ProgramData\AASHTOWare\BrDR683\Xsl Files\TrussPanelPointConct</pre>	Live Load Case Name	Element	at Node	Axial Force (kips)	Adjacent Vehicle
3	<pre>Panel_Point_Concurrent_Forces_Report></pre>	.	-	-	•	(kips) 👻
4	<pre>G<report_header></report_header></pre>	minCT-P120(6) - Permit Truck"T" Node1 Elemfx2	2	1	-123.60	-61.8
5	<pre><bridge name="">-1</bridge></pre>	maxCT_D120(6)Node1_Elemfy2	-	- 1	0.00	0
0	<pre><nsi_structure_id>046214/NBL_Structure_iD> </nsi_structure_id></pre>	maxcr-Pizo(0) - Permit mack T _Nodel_Elemitzz	2	1	0.00	0
8	<hr/>	minCI-P120(6) - Permit Truck"T"_Node1_Elemfx2	1	1	45.21	22.605
9	<analyze date="">Tuesday, July 9, 2019</analyze>	maxCT-P120(6) - Permit Truck"T"_Node1_Elemfx2	1	1	0.00	0
10	<analysis_engine>AASHTO Truss LRFR Engine Version 7.0.0.0</analysis_engine>	minCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	2	2	-123.60	-61.8
11	<report_by>patriacm</report_by>	maxCT-P120(6) - Permit Truck"T" Node2 Elemfx2	2	2	0.00	0
12	<pre><report_date>7/9/2019</report_date></pre>	minCT-P120(6) - Permit Truck"T" Node2 Elemfx2	3	2	-90.42	-45.21
14	<pre><kepott_stylesneet>C:\rfogrammata\AAShTOWare\bruktos\Asi files\frusspaneipointConcurrentForces.xsi </kepott_stylesneet></pre>	mayCT_D120(6) Permit Truck TT_Node2_Elemfy2	2	2	0.00	0
15	<pre> </pre> <pre></pre>		3	2	0.00	0
16	-	minC1-P120(6) - Permit Truck*1*_Node2_Elemtx2	4	2	92.93	46.465
17	口 <concurrent_forces></concurrent_forces>	maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx2	4	2	0.00	0
18	<pre><concurrent_forces_table></concurrent_forces_table></pre>	minCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	3	2	-120.26	-60.13
19	<concurrent_forces_table_header></concurrent_forces_table_header>	maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	3	2	0.00	0
21	<pre><free_unit <="" eees="" integ_unit="" pre="" seg=""></free_unit></pre>	minCT-P120(6) - Permit Truck"T" Node2 Elemfx3	2	2	-92.93	-46.465
22		max(T_P120(6) - Permit Truck"T" Node2 Elemfy3	2	2	0.00	0
23	A CPanel_Point>	miaCT P120(6) Permit Truck T _Node2_Elemits	2	2	0.00	46.465
24	C <name></name>	minC1-P120(6) - Permit Truck 1 _Node2_Elemix3	4	2	92.93	40.405
25	[CDATA[L0]]	maxCT-P120(6) - Permit Truck"T"_Node2_Elemfx3	4	2	0.00	0
26	<pre> </pre>	minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	6	3	-100.77	-50.385
28	<pre></pre>	maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	6	3	8.07	4.035
29	<pre><primary_member></primary_member></pre>	minCT-P120(6) - Permit Truck"T" Node3 Elemfx6	1	3	36.86	18.43
30	- And	maxCT-P120(6) - Permit Truck"T" Node3 Elemfx6	1	3	20.67	10.335
31	[CDATA[LOL1]]	minCT_D120(6) Dormit Truck "T" Nodo2_Elomfy6	-	2	110 57	55 205
32	<pre></pre>	milet-F120(d) - Fernit Truck T _Node3_Elemix0	5	3	110.57	10.105
34	<pre></pre> Critical Compression Live Load>	maxCI-P120(6) - Permit Truck*T*_Node3_Elemtx6	5	3	38.39	19.195
35	[CDATA[]]	minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	4	3	75.76	37.88
36	<pre>- </pre>	maxCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	4	3	42.49	21.245
37	<critical_tension_live_load></critical_tension_live_load>	minCT-P120(6) - Permit Truck"T"_Node3_Elemfx6	7	3	0.00	0
38	CT-Pl20(6] - Permit Truck	maxCT-P120(6) - Permit Truck"T" Node3 Elemfx6	7	3	0.00	0
39 40	Controlation_Live_Loads	min(T-P120(6) - Permit Truck"T" Node4 Elemfx3	2	4	-120.26	-60.13
41	T (Name>	marCT_P120(6) Permit Truck TNode4_Elemfx2	2	4	0.00	0
42	(CDATA[LOL1]]		5	4	0.00	0
43		minc1-P120(b) - Permit Truck"T"_Node4_Elemfx3	8	4	-90.42	-45.21
44	<compression force="" ll=""></compression>	maxCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	8	4	0.00	0
45	<pre>< rension_LL_Force>6U.13 </pre>	minCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	7	4	0.00	0
47		maxCT-P120(6) - Permit Truck"T"_Node4_Elemfx3	7	4	0.00	0
48	<pre></pre>	minCT-P120(6) - Permit Truck"T" Node4 Elemfx8	8	4	-120.26	-60.13
			0	-	120120	00115





Excel

Superimposing Loads

Compute EV D.F.



Compute Adjacent Lane Legal D.F.



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<u>Carry Out Rating</u>

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

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



<u>Block Shear</u>

• 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

	DW ANIOI											
ne	Load	Load Combo	Limit State	Axial LL (kip)	DC	DW	LL	PhiPn (kip)	Ovrride Phi	Ovrride Pn(kip)	RF	Capacity Note (Ton)
	DesignInv	14	STR-I	92.84	1.20	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
ne	DesignOp	14	STR-I	92.84	1.25	1.50	1.35	317.44			2.09	75.22
nell	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
1	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
1	LegalRoutine	20	STR-I	-41.78	1.00	1.00	1.30	-225.30			4.95	123.78

Half Through-Trusses







- **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

X



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

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Pin Connected Members

Pins Connecting Multiple Members: Rate Outside of BrR





<u>Summary</u>

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





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