

Steel Beam End Spreadsheet v2

Basic Instruction & Reference Manual

User input Data

This section discusses how the user will use the spreadsheet to compute ratings.

Basic Spreadsheet Organization & Operation

The spreadsheet is designed to analyze multiple beam ends. Each row of each sheet corresponds to one beam end. Each beam end is identified by three criteria: Span, Member, and Support. Each sheet starts with these three columns; all the inputs in that row are specific to that beam end. The order of the beam ends does not need to be the same on each sheet. There shall be no blank rows between inputs, the program will terminate when it encounters a blank row.

Section Properties Input

Stiffened Inputs

The Stiffened Inputs tab is used for input the beam original section properties and section losses for beam ends with bearing stiffeners. For the input of these variables see the schematic case I, II, and III.

Unstiffened Inputs

The Unstiffened Inputs tab is used for the inputs for the beam original section properties and section losses for beams ends without bearing stiffeners. For the input of these variables see the schematic case IV.

Loads

The Loads tab is used to input the reaction at each beam end. Either manual entry or AASHTOWare Automatic Import is supported. For AASHTOWare Automatic import see BrR Control for instructions.

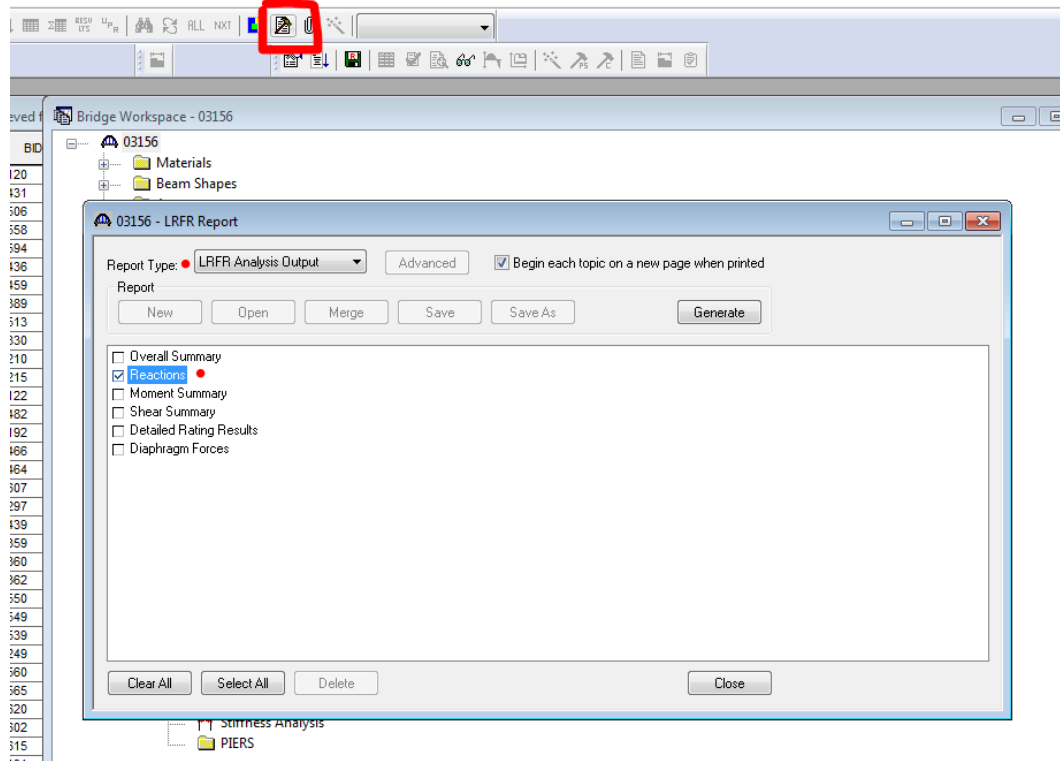
Load Factors

The Load Factors tab is used to input the Strength Load Factors for each beam end, and each loading. Either manual entry or automatic generate of the load factors are supported. For automatic generation a separate spreadsheet is used, "Permit Truck Live Load Factor_v1.xltm". This spreadsheet can be found on the CTDOT Bridge Load Rating Website, once downloaded set cell "N2" to the file path, by pressing the Custom Path button. By default the file path is set to the location of the spreadsheet for in-house bridge engineers. The Live Load Factors are dependent on Analysis Type, ADTT and Structure Length; enter this information in the orange boxes prior to selecting Generate Factors. Please note that if any of these fields are blank, they will analyze as a zero.

AASHTOWare Automatic Import

The *BrR Control* tab is used to automatically import the reaction forces generate by AASHTOWare into the spreadsheet. Input in this sheet is not required if AASHTOWare Automatic Input

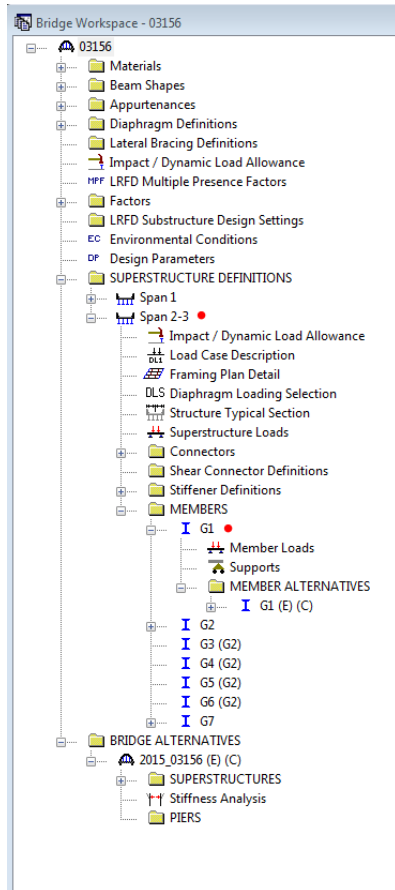
1. First the user should run the AASHTOWare model and generate a LRFR Report for Reactions.



2. Then set the LRFR Report Path to the report location by either the Default XML Path, or Custom XML Path buttons. The default button fill set the path to the default location on the user's machine, this button will only work correctly if the AASHTOWare report path is set to the users "D" drive my documents folder as on the state in-house engineer machine for BrR 6.7. If AASHTOWare is not defaulted to this location, or accessing a previously save LRFR report use the Custom XML Path button.
3. Then the user shall click the Import LRFR Report, and the Reactions will be imported into the LRFRReport sheet. This sheet will unhide itself when the button is pressed.
4. The user will then need link the Beam Identification to the AASHTOWare Beam Identification. The reason for this is that the spreadsheet may use a different identification logging and naming convention then used in AASHTOWare. Below is an example on how to link IDs.
 - a. For example structure consists of 3 spans, Span 1 is simple, and Span 2-3 is two spans continuous the input would look like this:

	A	B	C	D	E	F
1						
2		LRFR Report Path		D:\Users\patriacm\Documents\AASHTOWARE\BrDR67\Reports\LRFRReport.XML		
3						
4	Top	Default XML Path	Custom XML Path	Import LRFR Report	Input Loads	Save XML
5	Beam End Identification			AASHTOWare Beam Identification		
6	Span	Member	Support	Superstructure Definition	Member	Support
7	1	4	1	Span 1	G4	1
8	1	2	2	Span 1	G2	2
9	2	3	1	Span 2-3	G3	1
10	3	5	2	Span 2-3	G5	3

The names for the Superstructure Definition and Member Should match how they are inputted into AASHTOWare"



Note that the Member is the name by the red dot above, and not the Member Alternative name.

5. Click Input Loads to import the loads from to the *LRFR Report* sheet to the *Loads* tab.
6. The Save XML button will be used to save the LRFRReport for any future use. Include this file in the References folder upon submission.

Rating Factors

The final step is to select the *Rating Factors* Tab and click Preform Ratings button.

Review Results

The ratings for each vehicle and beam end can be found on the *Rating Factors* tab.

To review the intermediate calculations go to the *Unstiffened Outputs* tab, and *Stiffened Outputs* tab.

~~To see the governing rating factor for each vehicle go to the *Governing Ratings* Tab.~~

~~To see the Legal and Permit ratings less than 1.0 for the Report, go to the *Low Legal* and *Low Permit* tabs respectively.~~

Method for Solution

This section illustrates the methods used to analyze the beam ends. This serves as a verification that the spreadsheet is working correctly, by providing a "proof" or "sample" calculation. This section also serves to help load rating engineer understand the individual inputs and outputs of the spreadsheet related to the actual analysis. The load rating engineer should be able to easily follow the calculations to determine if the methods used are appropriate. It is the load rating engineer's responsibility to agree with the methods used herein, and shall accept ownership of the calculations, as with any other software the load rating engineer uses to perform their tasks.

These Mathcad sheets are available for download on the CTDOT Bridge Load Rating Website. The load rating engineer may use these Mathcad sheets if they prefer over the spreadsheet. The load rating engineer may modify the Mathcad sheets to customize the analysis for any specific conditions the load rating engineer believes it warrants. In this case the load rating engineer shall document the reasons why the Mathcad sheets were modified within the "Description" section of the Mathcad sheet, and add " – Modified" to the title of the Mathcad sheet.

Sample Calculation Index:

1. Stiffened Web
2. UnStiffened Web where Web Crippling Controls
3. UnStiffened Web where Web Local Yielding Controls
4. Spreadsheet Inputs – Stiffened Web Inputs
5. Spreadsheet Inputs – UnStiffened Web Inputs
6. Spreadsheet Inputs – Loads
7. Spreadsheet Inputs – Load Factors
8. Spreadsheet Outputs – Rating Factors
9. Spreadsheet Outputs – Stiffened Web Capacity Outputs
10. Spreadsheet Outputs – UnStiffened Web Capacity Outputs

1. Stiffened Web - Sample



Steel Beam Ends Load Rating-Stiffened Web

v1.0 6/30/2016

Description: The purpose of this worksheet is to compute rating factors for Steel Beams with bearing stiffeners, and provide a sample calculation for the approval of the CTDOT Beam End Spreadsheet v1.0

References:

MBE - AASHTO The Manual for Bridge Evaluation 2nd ed. 2014 with 2016 Interim Revisions
LRFD - AASHTO LRFD Bridge Design Specifications 7th ed. with 2016 Interim Revisions
BLRM - CTDOT Bridge Load Rating Manual v1.0

Bridge: 00000

Span: 4

Girder: 6

Location: Pier 4

Original Girder Section Properties

Web Depth	$d := 54\text{in}$	Inside Flange to Flange distance
Web Thickness	$t_w := \frac{3}{8}\text{in}$	
Web Yield Strength	$F_{yw} := 33\text{ksi}$	
Modulus Elasticity of steel	$E := 29000\text{ksi}$	
Minimum End Length	$L_{OH} := 8\text{in}$	Beam end to 1st stiffener distance
Stiffener Thickness	$t_p := \frac{5}{8}\text{in}$	
Stiffener Projecting Width	$b_t := 7\text{in}$	
Number of Stiffener Pairs	$N_p := 1$	
Stiffener Yield Strength	$F_{ys} := 33\text{ksi}$	
Distance between outer Stiffeners	$D_{stiff} := 0\text{in}$	
Connection	Connection := "Welded"	
	[None, Welded, Bolted]	
Fit	Fit := "Welded"	
	[Welded, Fitted]	

*Note Beam ends not rated based on stiffener bearing resistance

**Section Loss***Uniform Corrosion*

Web Thickness Loss	$SL_w := 2.5\%$
Stiffener Thickness Loss	$SL_{tp} := 10\%$
Stiffener Width Loss	$SL_{bt} := 5\%$

Localized Corrosion

Stiffener Width Loss in group A	$sl_{b,a} := 0\%$
Stiffener Thickness Loss in group A	$sl_{t,a} := 0\%$
Stiffener Width Loss in group B	$sl_{b,b} := 8.5\%$
Stiffener Thickness Loss in group B	$sl_{t,b} := 6\%$
Web Thickness Loss	$sl_{t,w,l} := 5\%$

**As-Inspected Girder Section Properties**

Web thickness $t_w := t_w \cdot (1 - SL_w) = 0.366 \text{ in}$

Stiffener Thickness $t_p := t_p \cdot (1 - SL_{tp}) = 0.563 \text{ in}$

Stiffener Width $b_t := b_t \cdot (1 - SL_{bt}) = 6.65 \text{ in}$

LRFD Resistance Factors, MBE 6A.6.3 & LRFD 6.5.4.2

For Bearing.. on milled surfaces

$\phi_b := 1.0$

For axial compression, steel only - (Dependent on Built Date)

$\phi_{comp} := 0.95$

LRFR Factors

System Factor, MBE 6A.4.2.4 & MBE Table 6A.4.2.4-1

$\phi_s := 1.0$

For All Other Girder Bridges and Slab Bridges

Condition Factor, MBE 6A.4.2.3 & MBE Table 6A.4.2.3-1

$\phi_c := 0.90$

Poor Condition + Increased by 0.05 for field measured losses, MBE C6A.4.2.3

**Beam Ends With Bearing Stiffeners, LRFD 6.10.11.2**

if(Connection = "None" , "This Section Not Applicable" , "This Section Applicable") = "This Section Applicable"

The following calculations are applicable only for Stiffened Beam Ends

Bearing Resistance, LRFD 6.10.11.2.3-3

if(Fit = "Fitted" , "This Section Applicable" , "This Section Not Applicable") = "This Section Not Applicable"

Determine area of projecting element

$$A_{pn} := 2 \cdot N_p \cdot t_p \cdot b_t = 7.481 \text{ in}^2$$

Compute Fitted End Bearing Resistance, LRFD 6.10.11.2.3-1 & 6.10.11.2.3-2

$$R_{sb} := \phi_b \cdot 1.4 \cdot A_{pn} \cdot F_{ys} = 345.634 \text{ kip}$$

Axial Resistance of Bearing Stiffeners, LRFD 6.10.11.2.4

Effective Section, LRFD 6.10.11.2.4b

$$ES := \begin{cases} (D_{stiff} + 9 \cdot t_w + \min(9 \cdot t_w, L_{OH})) \cdot \min\left(1, \frac{F_{yw}}{F_{ys}}\right) & \text{if Connection = "Welded"} \\ t_p & \text{otherwise} \end{cases} = 6.581 \text{ in}$$

General Requirements, LRFD 6.10.11.2.4a

Determine Moment of Inertia of Projecting Plate

$$I_s := \frac{N_p \cdot t_p \cdot \left(2 \cdot b_t + \frac{t_w}{1 - SL_w}\right)^3 + (ES - t_p \cdot N_p) \cdot t_w^3}{12} = 119.898 \text{ in}^4$$

Determine Gross Remaining Area

$$A_g := 2N_p \cdot t_p \cdot b_t + ES \cdot t_w = 9.888 \text{ in}^2$$

Determine radius of Gyration

$$r_s := \sqrt{\frac{I_s}{A_g}} = 3.482 \text{ in}$$

Effective Length Factor, LRFD 6.10.11.2.4.a

$$K_{eff} := 0.75$$

**Slender Member Elements, LRFD 6.9.4.2.2**

Per current AASHTO BDS, a Bearing Stiffener cannot be designed to be slender. For Load Rating purposes a bridge does not need to meet the AASHTO BDS design standards, however the reduced capacity of a slender Bearing Stiffener need be considered. Therefore the Element Reduction Factor not always taken equal to 1 per LRFD C6.9.4.1.1

Check Bearing Stiffener Slenderness, LRFD 6.10.11.2.2 - Projecting Width

$$\text{isSlenderStiff} := \text{if} \left(b_t \leq 0.48 t_p \cdot \sqrt{\frac{E}{F_{ys}}}, \text{"Compact"}, \text{"Slender"} \right) = \text{"Compact"}$$

Check Web Slenderness between Stiffeners, LRFD 6.9.4.2.1-1

$$\text{isSlenderWeb} := \begin{cases} \text{"N/A"} & \text{if } N_p = 1 \\ \text{"N/A"} & \\ \text{otherwise} & \\ \quad b \leftarrow \frac{D_{\text{stiff}}}{N_p - 1} & \\ \quad k \leftarrow 1.49 & \\ \quad \text{"Compact"} & \text{if } \frac{b}{t_w} \leq k \cdot \sqrt{\frac{E}{F_{yw}}} \\ \quad \text{"Slender"} & \text{otherwise} \end{cases}$$

Determine Slender Element Reduction Factor, LRFD 6.9.4.2.2

For outstanding legs of single angle; outstanding legs of double angles with separators; and all other unstiffened elements (stiffener):

$$Q_s := \begin{cases} 1 & \text{if } \text{isSlenderStiff} = \text{"Compact"} \\ \frac{0.53 E}{F_{ys} \cdot \left(\frac{b_t}{t_p} \right)^2} & \text{if } \frac{b_t}{t_p} > 0.91 \cdot \sqrt{\frac{E}{F_{ys}}} \\ 1.34 - 0.76 \left(\frac{b_t}{t_p} \right) \cdot \sqrt{\frac{F_{ys}}{E}} & \text{otherwise} \end{cases}$$



stiffened elements (web):

$$Q_a := \begin{cases} 1 & \text{if isSlenderWeb} \neq \text{"Slender"} \\ \text{otherwise} & \\ \quad f \leftarrow Q_s \cdot F_{yw} \\ \quad b \leftarrow \frac{D_{\text{stiff}}}{N_p - 1} \\ \quad b_e \leftarrow \min \left[b, 1.92 \cdot t_w \cdot \sqrt{\frac{E}{f}} \cdot \left[1 - 0.34 \left(\frac{b}{t_w} \right) \cdot \sqrt{\frac{E}{f}} \right] \right] \\ \quad A_{\text{eff}} \leftarrow A_g - (b - b_e) \cdot t_w \cdot (N_p - 1) \\ \quad \text{return } \frac{A_{\text{eff}}}{A_g} \end{cases} = 1$$

**Axial Compression, LRFD 6.9.2.1***Noncomposite Compression Members, LRFD 6.9.4*

$$Q := Q_s \cdot Q_a = 1$$

Elastic Flexural Buckling Resistance, LRFD 6.9.4.1.2-1

$$P_e := \frac{\pi^2 \cdot E}{\left(\frac{K_{eff} \cdot d}{r_s} \right)^2} \cdot A_g = 20921.836 \text{ kip}$$

Determine equivalent nominal yield resistance, LRFD 6.9.4.1

$$P_o := Q \cdot F_{ys} \cdot A_g = 326.288 \text{ kip}$$

Determine P_n , LRFD 6.9.4.1-1 & 6.9.4.1.1-2

$$P_n := \begin{cases} \left[0.658^{\left(\frac{P_o}{P_e} \right)} \right] \cdot P_o & \text{if } \frac{P_e}{P_o} \geq 0.44 \\ 0.877 \cdot P_e & \text{otherwise} \end{cases} = 324.165 \text{ kip}$$

Compressive Resistance of the Effective Section, LRFD 6.9.2.1-1

$$P_r := \phi_{comp} \cdot P_n = 307.957 \text{ kip}$$

**Loading**DC Load Factor $\gamma_{DC} := 1.25$ DW Load Factor $\gamma_{DW} := 1.50$ DC Load $DC := 46\text{-kip}$ DW Load $DW := 8.71\text{kip}$

Vehicle	Class	Load Factor	Load (kip)
HL-93	Inventory	1.75	64.66
HL-93	Operating	1.35	64.66
Type 3	Legal	1.45	35.07
Type 3S2	Legal	1.45	43.05
Type 3-3	Legal	1.45	43.92
SU4	Legal	1.45	38.37
SU5	Legal	1.45	43.2
SU6	Legal	1.45	46.8
SU7	Legal	1.45	50.39
CT-H20	Legal	1.45	29.77
CT-HS20	Legal	1.45	49.23
CT-L73.0	Legal	1.45	50.88
CT-L32S	Legal	1.45	42.78
CT-P76.5	Permit	1.30	54.27
CT-P120(6)	Permit	1.35	70.84
CT-P140(7)a	Permit	1.40	69.22
CT-P140(7)b	Permit	1.40	65.72
CT-P160(8)a	Permit	1.40	73.39
CT-P160(8)b	Permit	1.40	75.93
CT-P180(9)	Permit	1.35	80.39
CT-P200(10)	Permit	1.35	91.64
CT-P380	Permit	1.10	61.72

 $i := 0..21$

**Localized Corrosion Eccentricity Ratio, MBE C6A.6.5**

Distance from the N.A. to extreme fiber of original section

$$c := b_t + \frac{t_w}{2} = 6.833 \text{ in}$$

Load eccentricity in the member from corrosion

$$e := \frac{\frac{N_p \cdot t_p \cdot b_t^2}{2} \cdot \left[(1 - sl_{t,a}) \cdot (1 - sl_{b,a})^2 - (1 - sl_{t,b}) \cdot (1 - sl_{b,b})^2 \right]}{t_p \cdot b_t \cdot \left[(1 - sl_{t,a}) \cdot (1 - sl_{b,a}) + (1 - sl_{t,b}) \cdot (1 - sl_{b,b}) \right] + ES \cdot t_w \cdot (1 - sl_{t,w,l})} = 0.287 \text{ in}$$

Eccentricity Ratio

$$R_e := \frac{|e| c}{r_s^2} = 0.161$$

Axial Load Magnification Due to Localized Corrosion, MBE I6A

Total Factored Axial Loading

$$P_{u_i} := \gamma_{DC} \cdot DC + \gamma_{DW} \cdot DW + \gamma_{LL_i} \cdot LL_i \cdot \text{kip}$$

Axial load magnification factor, MBR I6A-1

$$\delta_{A_i} := \left(1 + R_e \cdot \sec \left(\frac{K_{eff} \cdot d}{2} \cdot \sqrt{\frac{P_{u_i}}{E \cdot I_s}} \right) \right)$$



Vehicle	Class	Axail Load	Mag. Factor
HL-93	Inventory	183.72	1.16325806
HL-93	Operating	157.86	1.16300757
Type 3	Legal	121.42	1.16265576
Type 3S2	Legal	132.99	1.16276734
Type 3-3	Legal	134.25	1.16277951
SU4	Legal	126.20	1.16270188
SU5	Legal	133.21	1.16276944
SU6	Legal	138.43	1.16281981
SU7	Legal	143.63	1.16287008
CT-H20	Legal	113.73	1.16258172
CT-HS20	Legal	141.95	1.16285383
CT-L73.0	Legal	144.34	1.16287694
CT-L32S	Legal	132.60	1.16276356
CT-P76.5	Permit	141.12	1.1628458
CT-P120(6)	Permit	166.20	1.1630883
CT-P140(7)a	Permit	167.47	1.16310064
CT-P140(7)b	Permit	162.57	1.16305321
CT-P160(8)a	Permit	173.31	1.16315717
CT-P160(8)b	Permit	176.87	1.16319163
CT-P180(9)	Permit	179.09	1.16321318
CT-P200(10)	Permit	194.28	1.1633605
CT-P380	Permit	138.46	1.16282012

**Rating****Determine Minimum Capacity**

$$R_n := P_r = 307.957 \text{ kip}$$

*Note Beam Ends not rated based on Stiffener Bearing

$$C := \max(0.85, \phi_s \cdot \phi_c) \cdot R_n = 277.161 \text{ kip}$$

Compute Ratings

$$RF_i := \frac{\frac{C}{\delta A_i} - \gamma_{DC} DC - \gamma_{DW} DW}{\gamma_{LL_i} \cdot LL_i} \cdot \text{kip}$$

Vehicle	Class	Rating
HL-93	Inventory	1.48
HL-93	Operating	1.92
Type 3	Legal	3.30
Type 3S2	Legal	2.68
Type 3-3	Legal	2.63
SU4	Legal	3.01
SU5	Legal	2.67
SU6	Legal	2.47
SU7	Legal	2.29
CT-H20	Legal	3.88
CT-HS20	Legal	2.35
CT-L73.0	Legal	2.27
CT-L32S	Legal	2.70
CT-P76.5	Permit	2.37
CT-P120(6)	Permit	1.75
CT-P140(7)a	Permit	1.73
CT-P140(7)b	Permit	1.82
CT-P160(8)a	Permit	1.63
CT-P160(8)b	Permit	1.57
CT-P180(9)	Permit	1.54
CT-P200(10)	Permit	1.35
CT-P380	Permit	2.47

2. UnStiffened Web - Sample - Web Crippling



Steel Beam Ends Load Rating-UnStiffened Web

v1.0 6/30/2016

Description: The purpose of this worksheet is to compute rating factors for Steel Beams without bearing stiffeners, and provide a sample calculation for the approval of the CTDOT Beam End Spreadsheet v1.0

References:

MBE - AASHTO The Manual for Bridge Evaluation 2nd ed. 2014 with 2016 Interim Revisions
LRFD - AASHTO LRFD Bridge Design Specifications 7th ed. with 2016 Interim Revisions
BLRM - CTDOT Bridge Load Rating Manual v1.0

Bridge: 00000

Span: 4

Girder: 6

Location: Pier 4

Orginal Girder Section

Section Depth	D	24 in
Web Thickness	t.w	0.5 in
Web Yield Strength	F.yw	70 ksi
E of Steel	E	29000 ksi
Flange Thickness	t.f	0.5 in
Flange + Fillet Thickness	K	0.75 in
Length of Bearing	N	12 in
Minimum End Length	L.OH	24 in
Web Thickness Loss	SL.w	40 %
Flange + Fillet Loss	SL.K	0 %
Flange Loss	SL.tf	0 %

Units

D := D·in
t_w := t_w·in
F_{yw} := F_{yw}·ksi
E := E·ksi
t_f := t_f·in
K := K·in
N := N·in
L_{OH} := L_{OH}·in
SL_w := SL_w·%
SL_K := SL_K·%
SL_{tf} := SL_{tf}·%

**As-Inspected Girder Section Properties**

Web thickness $t_w := t_w \cdot (1 - SL_w) = 0.3 \text{ in}$

Flange + Fillet $K := K \cdot (1 - SL_K) = 0.75 \text{ in}$

Flange $t_f := t_f \cdot (1 - SL_{tf}) = 0.5 \text{ in}$

LRFD Resistance Factors, MBE 6A.6.3 & LRFD 6.5.4.2

For Bearing.. on milled surfaces

$\phi_b := 1.0$

For axial compression, steel only - (Dependent on Built Date)

$\phi_c := 0.95$

For web crippling

$\phi_w := 0.80$

LRFR Factors

System Factor, MBE 6A.4.2.4 & MBE Table 6A.4.2.4-1

$\phi_s := 1.0$

For All Other Girder Bridges and Slab Bridges

Condition Factor, MBE 6A.4.2.3 & MBE Table 6A.4.2.3-1

$\phi_c := 0.90$

Poor Condition + Increased by 0.05 for field measured losses, MBE C6A.4.2.3

**Beam Ends Without Bearing Stiffeners, LRFD D6.5.2**

The following calculations are applicable only for Unstiffened Beam Ends

Web Local Yielding, LRFD D6.5.2

Nominal Resistance to the Concentrated Loading, LRFD D6.5.2-2 or D6.2.2-3

$$R_{nb} := \begin{cases} (5 \cdot K + N) \cdot F_{yw} \cdot t_w & \text{if } L_{OH} > D \\ \left(2.5 \cdot K + N + \min \left(2.5 \cdot K, \max \left(0, L_{OH} - \frac{N}{2} \right) \right) \right) \cdot F_{yw} \cdot t_w & \text{otherwise} \end{cases}$$

$$R_{nb} = 330.75 \text{ kip}$$

$$R_{ub} := \phi_b \cdot R_{nb} = 330.75 \text{ kip}$$

Web Crippling, LRFD D6.5.3

Nominal Resistance to the Concentrated Loading, LRFD D6.5.3-2, D6.5.3-3, or D6.5.3-4

$$R_{nw} := \begin{cases} \left[0.8 t_w^2 \cdot \left[1 + 3 \cdot \left(\frac{N}{D} \right) \cdot \left(\frac{t_w}{t_f} \right)^{1.5} \right] \cdot \sqrt{\frac{E \cdot F_{yw} \cdot t_f}{t_w}} \right] & \text{if } L_{OH} \geq \frac{D}{2} \\ \left[0.4 t_w^2 \cdot \left[1 + 3 \cdot \left(\frac{N}{D} \right) \cdot \left(\frac{t_w}{t_f} \right)^{1.5} \right] \cdot \sqrt{\frac{E \cdot F_{yw} \cdot t_f}{t_w}} \right] & \text{if } \frac{N}{D} \leq 0.2 \\ \left[0.4 t_w^2 \cdot \left[1 + \left(\frac{4N}{D} - 0.2 \right) \cdot \left(\frac{t_w}{t_f} \right)^{1.5} \right] \cdot \sqrt{\frac{E \cdot F_{yw} \cdot t_f}{t_w}} \right] & \text{otherwise} \end{cases}$$

$$R_{nw} = 224.761 \text{ kip}$$

$$R_{uw} := \phi_w \cdot R_{nw} = 179.809 \text{ kip}$$

**Loading**DC Load Factor $\gamma_{DC} := 1.25$ DW Load Factor $\gamma_{DW} := 1.50$ DC Load $DC := 46\text{kip}$ DW Load $DW := 8.71\text{kip}$

Vehicle	Class	Load Factor	Load (kip)
HL-93	Inventory	1.75	64.66
HL-93	Operating	1.35	64.66
Type 3	Legal	1.45	35.07
Type 3S2	Legal	1.45	43.05
Type 3-3	Legal	1.45	43.92
SU4	Legal	1.45	38.37
SU5	Legal	1.45	43.2
SU6	Legal	1.45	46.8
SU7	Legal	1.45	50.39
CT-H20	Legal	1.45	29.77
CT-HS20	Legal	1.45	49.23
CT-L73.0	Legal	1.45	50.88
CT-L32S	Legal	1.45	42.78
CT-P76.5	Permit	1.30	54.27
CT-P120(6)	Permit	1.35	70.84
CT-P140(7)a	Permit	1.40	69.22
CT-P140(7)b	Permit	1.40	65.72
CT-P160(8)a	Permit	1.40	73.39
CT-P160(8)b	Permit	1.40	75.93
CT-P180(9)	Permit	1.35	80.39
CT-P200(10)	Permit	1.35	91.64
CT-P380	Permit	1.10	61.72

 $i := 0..21$

**Rating**

Determine Minimum Capacity

$$R_n := \min(R_{ub}, R_{uw}) = 179.809 \text{ kip}$$

$$C := \max(0.85, \phi_s \cdot \phi_c) \cdot R_n = 161.828 \text{ kip}$$

Compute Ratings

$$RF_i := \frac{C - \gamma_{DC} \cdot DC - \gamma_{DW} \cdot DW}{\gamma_{LL_i} \cdot LL_i \cdot \text{kip}}$$

Vehicle	Class	Rating
HL-93	Inventory	0.80
HL-93	Operating	1.04
Type 3	Legal	1.79
Type 3S2	Legal	1.46
Type 3-3	Legal	1.43
SU4	Legal	1.64
SU5	Legal	1.45
SU6	Legal	1.34
SU7	Legal	1.24
CT-H20	Legal	2.11
CT-HS20	Legal	1.27
CT-L73.0	Legal	1.23
CT-L32S	Legal	1.47
CT-P76.5	Permit	1.29
CT-P120(6)	Permit	0.95
CT-P140(7)a	Permit	0.94
CT-P140(7)b	Permit	0.99
CT-P160(8)a	Permit	0.88
CT-P160(8)b	Permit	0.85
CT-P180(9)	Permit	0.84
CT-P200(10)	Permit	0.73
CT-P380	Permit	1.34

**Analysis Summary**

As-Inspected Web Thickness	t.w	0.3 in
As-Inspected Flange + Fillet Thickness	K	0.75 in
Web Local Yield Resistance	R.ub	330.75 kip
Web Crippling Resistance	R.uw	179.8091 kip
Factored Capacity	C	161.8282 kip

3. UnStiffened Web - Sample - Web Local Yielding



Steel Beam Ends Load Rating-UnStiffened Web

v1.0 6/30/2016

Description: The purpose of this worksheet is to compute rating factors for Steel Beams without bearing stiffeners, and provide a sample calculation for the approval of the CTDOT Beam End Spreadsheet v1.0

References:

MBE - AASHTO The Manual for Bridge Evaluation 2nd ed. 2014 with 2016 Interim Revisions
LRFD - AASHTO LRFD Bridge Design Specifications 7th ed. with 2016 Interim Revisions
BLRM - CTDOT Bridge Load Rating Manual v1.0

Bridge: 00000

Span: 4

Girder: 6

Location: Pier 4

Orginal Girder Section		
Section Depth	D	24 in
Web Thickness	t.w	0.5 in
Web Yield Strength	F.yw	70 ksi
E of Steel	E	29000 ksi
Flange Thickness	t.f	0.5 in
Flange + Fillet Thickness	K	0.75 in
Length of Bearing	N	12 in
Minimum End Length	L.OH	24 in
Web Thickness Loss	SL.w	0 %
Flange + Fillet Loss	SL.K	20 %
Flange Loss	SL.tf	3 %

Units

D := D·in

t_w := t_w·in

F_{yw} := F_{yw}·ksi

E := E·ksi

t_f := t_f·in

K := K·in

N := N·in

L_{OH} := L_{OH}·in

SL_w := SL_w·%

SL_K := SL_K·%

SL_{tf} := SL_{tf}·%

**As-Inspected Girder Section Properties**

Web thickness $t_w := t_w \cdot (1 - SL_w) = 0.5 \text{ in}$

Flange + Fillet $K := K \cdot (1 - SL_K) = 0.6 \text{ in}$

Flange $t_f := t_f \cdot (1 - SL_{tf}) = 0.4 \text{ in}$

LRFD Resistance Factors, MBE 6A.6.3 & LRFD 6.5.4.2

For Bearing.. on milled surfaces

$\phi_b := 1.0$

For axial compression, steel only - (Dependent on Built Date)

$\phi_c := 0.95$

For web crippling

$\phi_w := 0.80$

LRFR Factors

System Factor, MBE 6A.4.2.4 & MBE Table 6A.4.2.4-1

$\phi_s := 1.0$

For All Other Girder Bridges and Slab Bridges

Condition Factor, MBE 6A.4.2.3 & MBE Table 6A.4.2.3-1

$\phi_c := 0.90$

Poor Condition + Increased by 0.05 for field measured losses, MBE C6A.4.2.3

**Beam Ends Without Bearing Stiffeners, LRFD D6.5.2**

The following calculations are applicable only for Unstiffened Beam Ends

Web Local Yielding, LRFD D6.5.2

Nominal Resistance to the Concentrated Loading, LRFD D6.5.2-2 or D6.2.2-3

$$R_{nb} := \begin{cases} (5 \cdot K + N) \cdot F_{yw} \cdot t_w & \text{if } L_{OH} > D \\ \left(2.5 \cdot K + N + \min \left(2.5 \cdot K, \max \left(0, L_{OH} - \frac{N}{2} \right) \right) \right) \cdot F_{yw} \cdot t_w & \text{otherwise} \end{cases}$$

$$R_{nb} = 525 \text{ kip}$$

$$R_{ub} := \phi_b \cdot R_{nb} = 525 \text{ kip}$$

Web Crippling, LRFD D6.5.3

Nominal Resistance to the Concentrated Loading, LRFD D6.5.3-2, D6.5.3-3, or D6.5.3-4

$$R_{nw} := \begin{cases} \left[0.8 t_w^2 \cdot \left[1 + 3 \cdot \left(\frac{N}{D} \right) \cdot \left(\frac{t_w}{t_f} \right)^{1.5} \right] \cdot \sqrt{\frac{E \cdot F_{yw} \cdot t_f}{t_w}} \right] & \text{if } L_{OH} \geq \frac{D}{2} \\ \left[0.4 t_w^2 \cdot \left[1 + 3 \cdot \left(\frac{N}{D} \right) \cdot \left(\frac{t_w}{t_f} \right)^{1.5} \right] \cdot \sqrt{\frac{E \cdot F_{yw} \cdot t_f}{t_w}} \right] & \text{if } \frac{N}{D} \leq 0.2 \\ \left[0.4 t_w^2 \cdot \left[1 + \left(\frac{4N}{D} - 0.2 \right) \cdot \left(\frac{t_w}{t_f} \right)^{1.5} \right] \cdot \sqrt{\frac{E \cdot F_{yw} \cdot t_f}{t_w}} \right] & \text{otherwise} \end{cases}$$

$$R_{nw} = 789.165 \text{ kip}$$

$$R_{uw} := \phi_w \cdot R_{nw} = 631.332 \text{ kip}$$

**Loading**DC Load Factor $\gamma_{DC} := 1.25$ DW Load Factor $\gamma_{DW} := 1.50$ DC Load $DC := 46\text{kip}$ DW Load $DW := 8.71\text{kip}$

Vehicle	Class	Load Factor	Load (kip)
HL-93	Inventory	1.75	64.66
HL-93	Operating	1.35	64.66
Type 3	Legal	1.45	35.07
Type 3S2	Legal	1.45	43.05
Type 3-3	Legal	1.45	43.92
SU4	Legal	1.45	38.37
SU5	Legal	1.45	43.2
SU6	Legal	1.45	46.8
SU7	Legal	1.45	50.39
CT-H20	Legal	1.45	29.77
CT-HS20	Legal	1.45	49.23
CT-L73.0	Legal	1.45	50.88
CT-L32S	Legal	1.45	42.78
CT-P76.5	Permit	1.30	54.27
CT-P120(6)	Permit	1.35	70.84
CT-P140(7)a	Permit	1.40	69.22
CT-P140(7)b	Permit	1.40	65.72
CT-P160(8)a	Permit	1.40	73.39
CT-P160(8)b	Permit	1.40	75.93
CT-P180(9)	Permit	1.35	80.39
CT-P200(10)	Permit	1.35	91.64
CT-P380	Permit	1.10	61.72

 $i := 0..21$

**Rating**Determine Minimum Capacity

$$R_n := \min(R_{ub}, R_{uw}) = 525 \text{ kip}$$

$$C := \max(0.85, \phi_s \cdot \phi_c) \cdot R_n = 472.5 \text{ kip}$$

Compute Ratings

$$RF_i := \frac{C - \gamma_{DC} \cdot DC - \gamma_{DW} \cdot DW}{\gamma_{LL_i} \cdot LL_i \cdot \text{kip}}$$

Vehicle	Class	Rating
HL-93	Inventory	3.55
HL-93	Operating	4.60
Type 3	Legal	7.90
Type 3S2	Legal	6.43
Type 3-3	Legal	6.31
SU4	Legal	7.22
SU5	Legal	6.41
SU6	Legal	5.92
SU7	Legal	5.50
CT-H20	Legal	9.31
CT-HS20	Legal	5.63
CT-L73.0	Legal	5.44
CT-L32S	Legal	6.47
CT-P76.5	Permit	5.69
CT-P120(6)	Permit	4.20
CT-P140(7)a	Permit	4.14
CT-P140(7)b	Permit	4.36
CT-P160(8)a	Permit	3.91
CT-P160(8)b	Permit	3.78
CT-P180(9)	Permit	3.70
CT-P200(10)	Permit	3.24
CT-P380	Permit	5.92



Analysis Summary			
As-Inspected Web Thickness	t.w	0.5	in
As-Inspected Flange + Fillet Thickness	K	0.6	in
Web Local Yield Resistance	R.ub	525	kip
Web Crippling Resistance	R.uw	631.3322	kip
Factored Capacity	C	472.5	kip



4. Stiffened Web - Spreadsheet - Inputs

Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



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Stiffened Web Inputs

[MathCad Reference on Website](#)

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Beam End Identification			Resistance	System	Condition	Member Properties (in, ksi)					Stiffener Properties (in, ksi)						Uniform Section Loss (%)			Localized Section Losses (%)				
Span	Member	Support	ϕ	$\phi.s$	$\phi.c$	E	F.yw	L.OH	d	t.w	D.stiff	Connection	b.t	t.p	F.ys	Np	SL.w	SL.tp	SL.bt	sl.b.a	sl.t.a	sl.b.b	sl.t.b	sl.t.w.l
1	1	1	0.95	1	0.9	29000	33	8	54	0.375	0	Welded	7	0.625	33	1	2.50%	10.00%	5.00%			8.50%	6.00%	5.00%



5. UnStiffened Web - Spreadsheet - Inputs

Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



[<-Inputs](#) [BrR Cntrl ->](#)

UnStiffened Web Inputs

$\phi.b$	1
$\phi.w$	0.8

[MathCad Refence on Website](#)

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Beam End Identification			System	Condition	Member Properties								Section Loss (%)		
Span	Member	Support	$\phi.s$	$\phi.c$	E	F.yw	D	t.w	t.f	K	L.OH	N	SL.w	SL.tf	SL.K
3	1	1	1	0.9	29000	70	24	0.5	0.5	0.75	24	12	40.00%		
4	1	1	1	0.9	29000	70	24	0.5	0.5	0.75	24	12		20.00%	3.00%



6. Spreadsheet - Loads

Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



[<-BrR Cntrl](#) [Factors->](#)

Loads

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Beam End Identification			Dead Load		INVENTORY	OPERATING	AASHTO LEGAL							CT LEGAL				CT PERMIT									
Span	Member	Support	DC	DW	HL-93	HL-93	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	H-20	HS-20	CT-L73.0	CT-L3S2	CT-P76.5	CT-P120(6)	CT-P140(7)a	CT-P140(7)b	CT-P160(8)a	CT-P160(8)b	CT-P180(9)	CT-P200(10)	CT-P380	
1	1	1	46	8.71	64.66	64.66	35.07	43.05	43.92	38.37	43.2	46.8	50.39	29.77	49.23	50.88	42.78	54.27	70.84	69.22	65.72	73.39	75.93	80.39	91.64	61.72	
3	1	1	46	8.71	64.66	64.66	35.07	43.05	43.92	38.37	43.2	46.8	50.39	29.77	49.23	50.88	42.78	54.27	70.84	69.22	65.72	73.39	75.93	80.39	91.64	61.72	
4	1	1	46	8.71	64.66	64.66	35.07	43.05	43.92	38.37	43.2	46.8	50.39	29.77	49.23	50.88	42.78	54.27	70.84	69.22	65.72	73.39	75.93	80.39	91.64	61.72	

7. Spreadsheet - Load Factors



Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



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Load Factors

Analysis	Other
ADTT	5000

DC	1.25
DW	1.50

Inventory	1.75
Operating	1.35

Live Load Factor Path [X:\Z_V8_CTDOT_NON_PROJECTS\Struct_Bridge\A_Bridge_Load_Rating\Templates\Permit Truck Live Load Factor_v1.xltn](#)

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Beam End Identification			Structure	Dead Load		INVENTORY	OPERATING	AASHTO LEGAL							CT LEGAL				CT PERMIT									
Span	Member	Support	Length	DC	DW	HL-93	HL-93	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	H-20	HS-20	CT-L73.0	CT-L352	CT-P76.5	CT-P120(6)	CT-P140(7)a	CT-P140(7)b	CT-P160(8)a	CT-P160(8)b	CT-P180(9)	CT-P200(10)	CT-P380	
1	1	1	130	1.25	1.5	1.75	1.35	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.3	1.35	1.4	1.4	1.4	1.4	1.4	1.4	1.35	1.1
3	1	1	130	1.25	1.5	1.75	1.35	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.3	1.35	1.4	1.4	1.4	1.4	1.4	1.4	1.35	1.1
4	1	1	130	1.25	1.5	1.75	1.35	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.3	1.35	1.4	1.4	1.4	1.4	1.4	1.4	1.35	1.1



8. Spreadsheet - Rating Factors

Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



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Beam End Identification				Vehicle		Rating		Loading						Capacity	Axial Magnification	
Span	Member	Support	S.M.S	Vehicle	Load Type	RF	Failure Mechanism	γ _{DC}	DC	γ _{DW}	DW	γ _{LL}	LL	C	P.u	δ.A
1	1	1	1.1.1	HL-93	INVENTORY	1.48	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.75	64.66	277.1608615	183.72	1.161528807
1	1	1	1.1.1	HL-93	OPERATING	1.92	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.35	64.66	277.1608615	157.856	1.161528783
1	1	1	1.1.1	Type 3	AASHTO LEGAL	3.3	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	35.07	277.1608615	121.4165	1.161528755
1	1	1	1.1.1	Type 3S2	AASHTO LEGAL	2.69	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	43.05	277.1608615	132.9875	1.161528763
1	1	1	1.1.1	Type 3-3	AASHTO LEGAL	2.63	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	43.92	277.1608615	134.249	1.161528764
1	1	1	1.1.1	SU4	AASHTO LEGAL	3.02	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	38.37	277.1608615	126.2015	1.161528758
1	1	1	1.1.1	SU5	AASHTO LEGAL	2.68	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	43.2	277.1608615	133.205	1.161528763
1	1	1	1.1.1	SU6	AASHTO LEGAL	2.47	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	46.8	277.1608615	138.425	1.161528767
1	1	1	1.1.1	SU7	AASHTO LEGAL	2.3	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	50.39	277.1608615	143.6305	1.161528771
1	1	1	1.1.1	H-20	CT LEGAL	3.89	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	29.77	277.1608615	113.7315	1.16152875
1	1	1	1.1.1	HS-20	CT LEGAL	2.35	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	49.23	277.1608615	141.9485	1.16152877
1	1	1	1.1.1	CT-L73.0	CT LEGAL	2.27	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	50.88	277.1608615	144.341	1.161528772
1	1	1	1.1.1	CT-L3S2	CT LEGAL	2.7	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.45	42.78	277.1608615	132.596	1.161528763
1	1	1	1.1.1	CT-P76.5	CT PERMIT	2.38	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.3	54.27	277.1608615	141.116	1.161528769
1	1	1	1.1.1	CT-P120(6)	CT PERMIT	1.75	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.35	70.84	277.1608615	166.199	1.16152879
1	1	1	1.1.1	CT-P140(7)a	CT PERMIT	1.73	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.4	69.22	277.1608615	167.473	1.161528791
1	1	1	1.1.1	CT-P140(7)b	CT PERMIT	1.82	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.4	65.72	277.1608615	162.573	1.161528787
1	1	1	1.1.1	CT-P160(8)a	CT PERMIT	1.63	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.4	73.39	277.1608615	173.311	1.161528797
1	1	1	1.1.1	CT-P160(8)b	CT PERMIT	1.58	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.4	75.93	277.1608615	176.867	1.1615288
1	1	1	1.1.1	CT-P180(9)	CT PERMIT	1.49	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.4	80.39	277.1608615	183.111	1.161528806
1	1	1	1.1.1	CT-P200(10)	CT PERMIT	1.35	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.35	91.64	277.1608615	194.279	1.161528818
1	1	1	1.1.1	CT-P380	CT PERMIT	2.47	Stiffened Web - Flexural Buckling	1.25	46	1.5	8.71	1.1	61.72	277.1608615	138.457	1.161528767
3	1	1	3.1.1	HL-93	INVENTORY	0.8	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.75	64.66	161.8282319	183.72	1
3	1	1	3.1.1	HL-93	OPERATING	1.04	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.35	64.66	161.8282319	157.856	1
3	1	1	3.1.1	Type 3	AASHTO LEGAL	1.79	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	35.07	161.8282319	121.4165	1
3	1	1	3.1.1	Type 3S2	AASHTO LEGAL	1.46	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	43.05	161.8282319	132.9875	1
3	1	1	3.1.1	Type 3-3	AASHTO LEGAL	1.43	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	43.92	161.8282319	134.249	1
3	1	1	3.1.1	SU4	AASHTO LEGAL	1.64	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	38.37	161.8282319	126.2015	1
3	1	1	3.1.1	SU5	AASHTO LEGAL	1.45	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	43.2	161.8282319	133.205	1
3	1	1	3.1.1	SU6	AASHTO LEGAL	1.34	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	46.8	161.8282319	138.425	1
3	1	1	3.1.1	SU7	AASHTO LEGAL	1.24	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	50.39	161.8282319	143.6305	1
3	1	1	3.1.1	H-20	CT LEGAL	2.11	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	29.77	161.8282319	113.7315	1
3	1	1	3.1.1	HS-20	CT LEGAL	1.27	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	49.23	161.8282319	141.9485	1
3	1	1	3.1.1	CT-L73.0	CT LEGAL	1.23	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	50.88	161.8282319	144.341	1
3	1	1	3.1.1	CT-L3S2	CT LEGAL	1.47	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.45	42.78	161.8282319	132.596	1
3	1	1	3.1.1	CT-P76.5	CT PERMIT	1.29	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.3	54.27	161.8282319	141.116	1
3	1	1	3.1.1	CT-P120(6)	CT PERMIT	0.95	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.35	70.84	161.8282319	166.199	1
3	1	1	3.1.1	CT-P140(7)a	CT PERMIT	0.94	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.4	69.22	161.8282319	167.473	1
3	1	1	3.1.1	CT-P140(7)b	CT PERMIT	0.99	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.4	65.72	161.8282319	162.573	1
3	1	1	3.1.1	CT-P160(8)a	CT PERMIT	0.88	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.4	73.39	161.8282319	173.311	1
3	1	1	3.1.1	CT-P160(8)b	CT PERMIT	0.85	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.4	75.93	161.8282319	176.867	1
3	1	1	3.1.1	CT-P180(9)	CT PERMIT	0.81	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.4	80.39	161.8282319	183.111	1
3	1	1	3.1.1	CT-P200(10)	CT PERMIT	0.73	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.35	91.64	161.8282319	194.279	1
3	1	1	3.1.1	CT-P380	CT PERMIT	1.34	UnStiffened Web - Web Crippling	1.25	46	1.5	8.71	1.1	61.72	161.8282319	138.457	1
4	1	1	4.1.1	HL-93	INVENTORY	3.72	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.75	64.66	492.58125	183.72	1
4	1	1	4.1.1	HL-93	OPERATING	4.83	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.35	64.66	492.58125	157.856	1
4	1	1	4.1.1	Type 3	AASHTO LEGAL	8.29	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	35.07	492.58125	121.4165	1
4	1	1	4.1.1	Type 3S2	AASHTO LEGAL	6.76	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	43.05	492.58125	132.9875	1
4	1	1	4.1.1	Type 3-3	AASHTO LEGAL	6.62	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	43.92	492.58125	134.249	1
4	1	1	4.1.1	SU4	AASHTO LEGAL	7.58	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	38.37	492.58125	126.2015	1
4	1	1	4.1.1	SU5	AASHTO LEGAL	6.73	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	43.2	492.58125	133.205	1
4	1	1	4.1.1	SU6	AASHTO LEGAL	6.21	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	46.8	492.58125	138.425	1
4	1	1	4.1.1	SU7	AASHTO LEGAL	5.77	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	50.39	492.58125	143.6305	1



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Beam End Identification				Vehicle		Rating		Loading						Capacity	Axial Magnification	
Span	Member	Support	S.M.S	Vehicle	Load Type	RF	Failure Mechanism	γ .DC	DC	γ .DW	DW	γ .LL	LL	C	P.u	δ .A
4	1	1	4.1.1	H-20	CT LEGAL	9.77	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	29.77	492.58125	113.7315	1
4	1	1	4.1.1	HS-20	CT LEGAL	5.91	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	49.23	492.58125	141.9485	1
4	1	1	4.1.1	CT-L73.0	CT LEGAL	5.72	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	50.88	492.58125	144.341	1
4	1	1	4.1.1	CT-L3S2	CT LEGAL	6.8	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.45	42.78	492.58125	132.596	1
4	1	1	4.1.1	CT-P76.5	CT PERMIT	5.98	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.3	54.27	492.58125	141.116	1
4	1	1	4.1.1	CT-P120(6)	CT PERMIT	4.41	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.35	70.84	492.58125	166.199	1
4	1	1	4.1.1	CT-P140(7)a	CT PERMIT	4.35	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.4	69.22	492.58125	167.473	1
4	1	1	4.1.1	CT-P140(7)b	CT PERMIT	4.58	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.4	65.72	492.58125	162.573	1
4	1	1	4.1.1	CT-P160(8)a	CT PERMIT	4.1	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.4	73.39	492.58125	173.311	1
4	1	1	4.1.1	CT-P160(8)b	CT PERMIT	3.96	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.4	75.93	492.58125	176.867	1
4	1	1	4.1.1	CT-P180(9)	CT PERMIT	3.74	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.4	80.39	492.58125	183.111	1
4	1	1	4.1.1	CT-P200(10)	CT PERMIT	3.41	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.35	91.64	492.58125	194.279	1
4	1	1	4.1.1	CT-P380	CT PERMIT	6.21	UnStiffened Web - Web Local Yielding	1.25	46	1.5	8.71	1.1	61.72	492.58125	138.457	1



9. Stiffened Web - Spreadsheet - Capacity

Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



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Stiffened Web Capacity Outputs

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Beam End Identification			Capacity	As-Inspected Section			As-Inspected Section Properties					Eccentricity Ratio			Slenderness				Axial Resistance			
Span	Member	Support	C	t.w	t.p	b.t	ES	I.s	A.g	r.s	K.eff	c	e	R.e	isSlenderStiff	isSlenderWeb	Q.s	Q.a	P.e	P.o	P.n	P.r
1	1	1	277.1609	0.365625	0.5625	6.65	6.58125	119.8712	9.88752	3.48188	0.75	6.832813	0.286601	0.161528714	FALSE	FALSE	1	1	20917.16	326.2881	324.1648	307.9565

10. UnStiffened Web - Spreadsheet - Capacity



Steel Beam Ends - Stiffened Webs - Load Rating
Connecticut Department of Transportation



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UnStiffened Web Capacity Outputs

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Beam End Identification			Capactiy	As-Inspected Section		Resistance	
Span	Member	Support	C	t.w	K	R.ub	R.uw
3	1	1	161.8282	0.3	0.75	330.75	179.8091
4	1	1	492.5813	0.5	0.7275	547.3125	631.3322