TBLRP-LFR
USER GUIDE

VERSION 05242024

Table of Contents

List of Figures

List of Tables

Revisions

1. TBLRP-LFR was developed to replace the original TBLRP software for use by TxDOT and TxDOT's contracted consultants.
2. TBLRP-LFR was developed to assist with the transition towards LFR analysis for Steel structures.
3. This TBLRP-LFR User Guide has been created to assist users with the use and understanding of TBLRP-LFR.
4. The flatcar module was inserted into TBLRP-LFR in version 4.0.1. The User Guide was updated to account for this additional module to the software.
5. The concrete substructure module was removed from TBLRP-LFR in version 4.0.1. The User Guide was updated to account for this adjustment to the software.
6. T3, T3S2, T3-3, and NRL trucks were added to TBLRP-LFR in version 4.0.2. Modules were adjusted to account for these additional trucks. The User Guide was updated to account for the new trucks.
7. Inputs within modules were updated in version 4.0.2 to improve user experience. The User Guide was updated to account for these changes.
8. AISC steel HP, S, and W shapes were added to beam, cap, and pile designation drop down lists.
9. Additional Appendices were added to further explain analysis performed within macro buttons.

Section 1: General Info For The User

Welcome to the Texas Bridge Load Rating Program - Load Factor Rating (TBLRP-LFR) User Guide!

This Excel spreadsheet was developed as a tool to efficiently load rate Off-System bridges and bridge elements in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Load Factor Design (LFD) methodology for concrete and steel elements, and Allowable Stress Design (ASD) for timber elements and steel pile assumed subsurface capacity analysis. It is not appropriate for performing load ratings of bridges or bridge elements designed in conformance with AASHTO Load and Resistance Factor Design (LRFD) methodology.

Program Limitations:

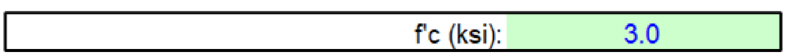
TBLRP-LFR has limitations on the types of elements it can load rate. Specific structures that should not be analyzed with this software are as follows:

- Truss Structures
- Concrete Superstructure Members (this includes concrete flat slabs and haunched slabs)
- Concrete Substructure Units
- Culverts
- Corrugated Metal Pipes
- Masonry Arches

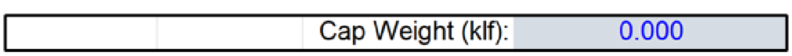
In the event that an element or structure does not fit within the bounds of this program, other forms of analysis are required. It is the responsibility of the Engineer of Record to verify the inputs are correct and interpret the results of the program.

Program Cell Color Scheme and Typical Nomenclature:

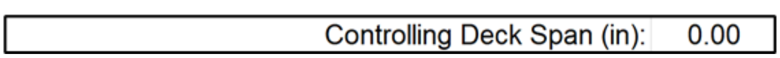
Green cells with blue text indicate an input cell.



Gray cells with blue text indicate a cell performs a calculation, but can be overwritten with an input.



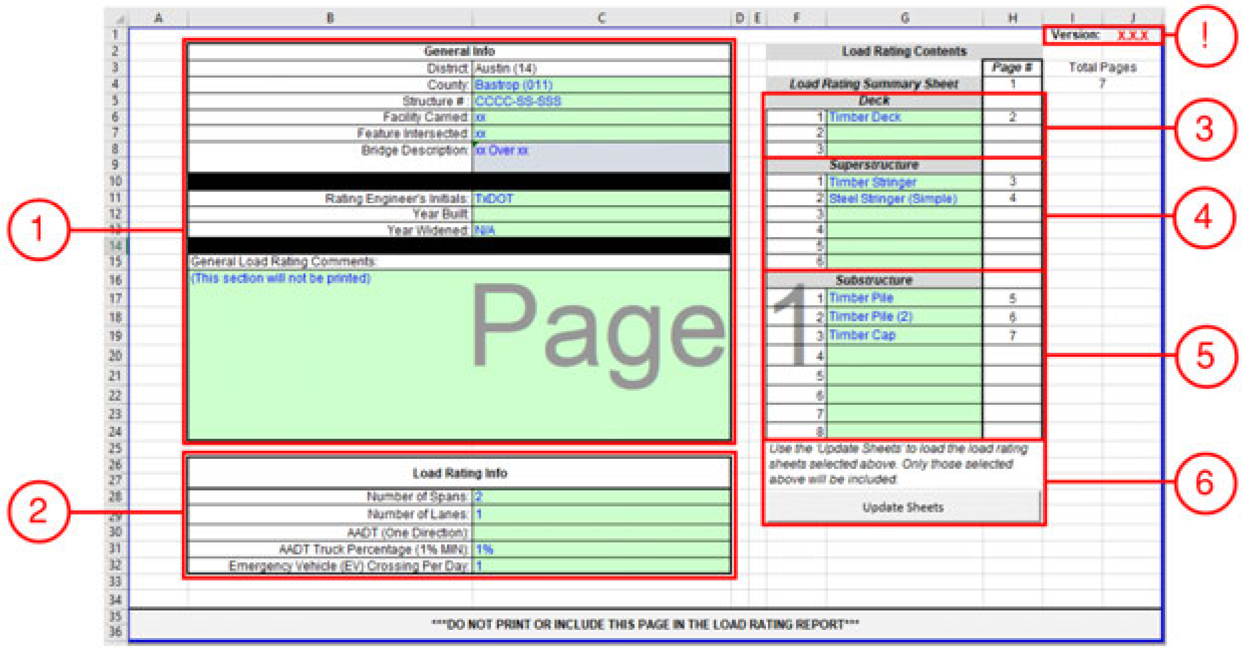
White cells with black text indicate a locked cell that performs a calculation or imports a value from another module.



Units:

Make sure to input all values per the units shown!

Section 2: Startup Page



Disclaimers:

- *Prior to beginning the load rating, ensure the most recent version of the software (as seen in the top right-hand corner of the Startup Page) is being used:*

  Version: X.X.X

- *Macros* ***must*** *be enabled for this spreadsheet to function properly.*
  - *If there are issues enabling macros due to Microsoft's security protocol (or internal company policies in place), please visit Microsoft Office's website to learn more on how to enable macros safely.*

When opening the spreadsheet, two tabs will be visible at the bottom of the page:

a. Startup Page
b. Load Rating Summary

Additional tabs will become visible and editable as more information is input into the Startup Page.

1. **General Info**
    a. ***District –*** This cell is not editable and will update automatically based upon the County selected below.
    b. ***County*** - Select the county for the bridge being analyzed from the dropdown list.
        i. This will update the District accordingly.
    c. ***Structure # –*** Input the bridge's structure number in the standard TxDOT format shown:
        i. *"CCCC*-SS-SSS"
    d. ***Facility Carried –*** Input the facility carried (travelway on bridge) for the structure being analyzed.
    e. ***Feature Intersected –*** Input the feature intersected (travelway(s) under bridge, stream(s) crossing under bridge, or both) for the structure being analyzed.
    f. ***Location*** - Once the Facility Carried and Feature Intersected are updated, the Location will update accordingly. If desired, the user can input their own description versus the standard presentation for this spreadsheet.
    g. ***Rating Engineer's Initials –*** Input the initials for the engineer load rating the structure with the TBLRP-LFR software.
    h. ***Year Built –*** Input the year in which the structure was built.
        i. *This year will be referenced in other tabs to estimate material properties.*
        ii. These estimated properties shall be overwritten if additional information is known on the material used.
    i. ***Year Widened –*** Input the year in which the structure was widened or rehabilitated.
    j. ***General Load Rating Comments*** – Use this section for any additional information towards others that might be viewing this Excel document. These comments shall not be printed in the final report.
2. **Load Rating Info**
    a. ***Number of Spans*** – Select the number of spans being analyzed.
        i. This cell is not referenced in other modules and is information only towards the user.
    b. ***Number of Lanes*** – Select 1 or 2 lanes from the drop-down list.
        i. The number of lanes selected will be referenced in some modules and utilized for their analysis when calculating recommended live load distribution factors.
    c. ***AADT*** – Input the Annual Average Daily Traffic in one direction for the structure being analyzed.
        i. This cell will be referenced in other modules and used to calculate recommended Emergency Vehicle Operating Live Load Factors.
    d. ***AADT Truck Percentage (1% Min)*** – Input the Average Annual Daily Traffic Truck percentage for the structure being analyzed.
        i. This cell will be referenced in other modules and used to calculate recommended Emergency Vehicle Operating Live Load Factors.
        ii. A minimum of 1% must be input in this cell.
        iii. AADT and Truck Percentage can be found on the Transportation Planning Map on the TxDOT website, and Item 29 and Item 109 on AssetWise.

e. ***Emergency Vehicle (EV) Crossing Per Day*** – Select 1 or 10 from the drop-down list.
    i. This cell will be referenced in other modules and used to calculate recommended Emergency Vehicle Operating Live Load Factors.
    ii. 10 EV crossings per day would be appropriate for urban regions, while 1 EV crossing per day would be appropriate for rural regions.

3. **Load Rating Contents**
    a. ***Decks*** - Select the deck type(s) to be included in this load rating from each cell's dropdown list. The available decks for analysis are as follows:
        i. Concrete Deck
        ii. Steel Deck (Steel Plate Deck, Steel Corrugated Deck, Steel Open Grid Deck)
        iii. Timber Deck
    b. ***Superstructure*** – Select the superstructure type(s) from each cell's dropdown list. The available superstructures for analysis are as follows:
        i. Steel Stringer (Simple Span Analysis)
        ii. Steel Stringer (Continuous Span Analysis)
        iii. Steel Floorbeam (Girder Stringer Floorbeam System)
        iv. Steel Girder (Simple Span Analysis, Girder Stringer Floorbeam System)
        v. Timber Stringer (Simple and Continuous Span Analysis)
        vi. Steel Flatcar (Simple and Continuous Span Analysis)
    c. ***Substructure*** – Select the substructure type(s) from each cell's dropdown list. The available substructures for analysis are as follows:
        i. Steel Cap
        ii. Steel Pile
        iii. Timber Cap
        iv. Timber Pile

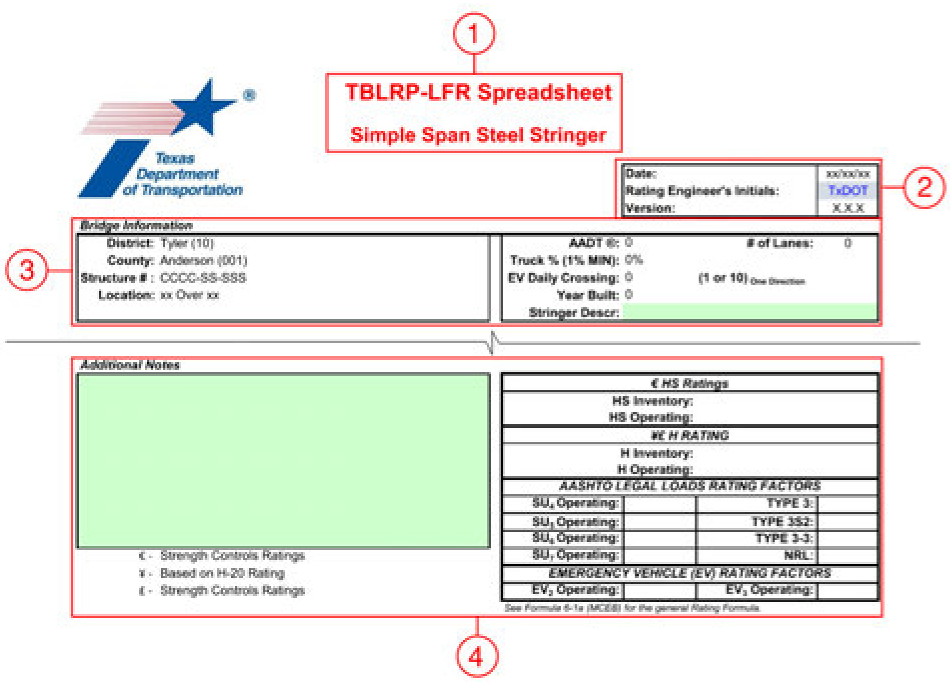
        Duplicate modules are provided for the user to include multiple analysis modules for the following superstructure/substructure types:
        a) Steel Stringer (Simple) (2)
        b) Timber Stringer (2)
        c) Steel Cap (2)
        d) Steel Pile (2)
        e) Timber Cap (2)
        f) Timber Pile (2)

4. **Update Sheets**
    a. Click the Update Sheets button after all elements that will be analyzed within the spreadsheet have been selected.
        i. <u>Macros must be enabled for this to run.</u>
    b. The modules will become available as tabs, located at the bottom of the screen.

Section 3: Typical Module (Tab) Info

The Modules within TBLRP-LFR generally follow a similar format. The standard layout of these modules are as follows:

1. **General Information**
    a. ***Module Heading*** – The current module will be displayed at the top of the screen.
        i. When a module utilizes Allowable Stress for its analysis, it will be noted adjacent to the Module's heading.
2. **Spreadsheet Identifier**
    a. ***Date*** – Provides the current date.
    b. ***Rating Engineer's Initials*** – As input on the Startup Page, but can be edited for multiple load raters working on the same structure.
    c. ***Version*** – Provides the version of TBLRP-LFR.
3. **Bridge Information**
    a. Information input from Startup Page will be shown here.
    b. ***Element Description*** – Input a description for this module's element. This description will be shown for each rated element on the Summary Sheet. (Example: S10 x 25.4 Exterior Girder, 5% SL).
4. **Ratings**
    a. ***H/HS Ratings*** – Calculated H/HS Ratings.
    b. ***SHV Rating Factors*** – Calculated SHV Rating Factors.
    c. ***EV Rating Factors*** – Calculated EV Rating Factors.
    d. ***Additional Notes*** – Area provided for the load rater to write any assumptions made or to provide clarification on the analysis.
    e. ***€ § ¥ £ Symbols*** – Additional information at the bottom of each module for Load Rating Engineers' reference.



Section 4: Load Rating Summary

1. **Components and Load Ratings**
    a. This section summarizes the load ratings of the modules selected on the Startup Page.
    b. ***Description*** – The description entered in the Bridge Information section of each module is displayed here.
    c. ***H/HS Inventory/Operating*** - The Inventory and Operating values for the H/HS trucks are summarized in this section.
2. **Controlling Component**
    a. The controlling load ratings for each truck as well as the component controlling the load rating values are displayed here.
3. **Additional Notes**
    a. Area provided to include additional notes.
4. **Print Tab Buttons**
    a. ***Print Prepare*** - Select this button, found to the right of the printed section, to hide all non-load rated sheets in the load rating.
    b. ***Show/Hide*** - Select any one of the four buttons, found to the right of the printed section, to show or hide the Startup Page, LIVE LOADS TABLE, Rating Factor Database, or the TX Standard Beam Shapes Table.

Additional information for the truck configurations evaluated within TBLRP-LFR is shown in *Appendix B*.

Section 5: Concrete Deck (Without Plans)

1. **RATING GUIDANCE NOTE**
    a. Load rating of the concrete deck must be performed if the deck thickness is less than 6" or the condition rating is 4 or less.
        i. This message is shown when these conditions are met.
2. **DATA INPUT TABLE**
    a. ***Deck Condition Rating*** – Input the condition rating for the concrete deck per the most recent inspection performed.
    b. ***Deck Thickness (in) –*** Input the overall concrete deck thickness.
        i. This value will be used for dead loads within other tabs when referencing the Concrete Deck module.
    c. ***Assumed Eff. Deck Thickness (d) (in)*** – Input the concrete deck thickness for which analysis is desired.
        i. This value is used to determine the Punching Shear Perimeter and Shear Live Load without impact values in the Punching Shear Analysis section below.
        ii. Within design, this value is typically 1.5" less than the overall deck thickness.
        iii. This value should be adjusted at the Engineer's discretion.
    d. ***f'_c (ksi)*** – Input the compressive strength of concrete for the deck.
        i. Additional guidance for recommended f'c values can be found to the right of the DATA INPUT TABLE.
    e. ***LL Impact*** – Input the live load impact factor used in analysis below.
        i. 1.3 is a standard impact factor for most load rating scenarios.
        ii. This value should be adjusted at the Engineer's discretion.
3. **RECOMMENDED f'c of CONCRETE DECK [Reference Table]**
    a. Users can reference this table for unknown concrete compressive strengths based upon the deck's condition rating per the most recent inspection performed.
4. **TIRE CONTACT AREA**
    a. The standard tire used for analysis is a 10" x 20" area based upon vehicle wheel loads acting on the concrete deck.
        i. βc – This is the ratio of Width (c2) to Length (c1)
5. **DEAD LOAD INPUTS**
    a. The dead load values input into this section are not used within the Concrete Deck analysis. These values are used for deck dead loads in the superstructure and substructure modules.
    b. ***Wearing Surface Thickness (in)*** – Input the wearing surface thickness used for analysis.
        i. This value will be referenced in other modules when pulling in concrete deck dead load values.
    c. ***Wearing Surface Material Unit Weight (kcf)*** – Input the unit weight of the wearing surface desired for analysis.
        i. See *Appendix A*.

d. ***Fill Material Depth (in)*** – Input the depth of fill atop the deck that is used for dead load calculations.
e. ***Fill Material Unit Weight (kcf)*** – Input the unit weight of the fill material used for dead load calculations.
f. ***Misc. Dead Load (ksf)*** – Input any additional weight (in kips per square feet) acting on the deck used for dead load calculations.

6. **Punching Shear Analysis**
   a. The Concrete Deck Module utilizes punching shear analysis to generate ratings.
      i. This module conservatively performs this analysis with the assumption that steel is not present within the deck.
   b. This analysis is based upon a wheel load being applied directly to the deck. The tire contact area values do not increase per the wearing surface depth or fill depth within TBLRP-LFR's analysis.
   c. **Concrete Deck Shear Capacity (V_c)** – This section calculates the shear capacity for the concrete deck.
      i. The shear capacity is calculated as follows:
      $V_c = (.8 + 2 / \beta c) * \sqrt{(f'c)} < 1.8 * \sqrt{(f'c)}$ (Eq. 5-1)
   d. **Punching Shear Perimeter (b_o)** – This section calculates the punching shear perimeter for the concrete deck.
      i. The punching shear perimeter is calculated as follows:
      $b_o = 2 * (c_1 + c_2) + 4 * d$ (Eq. 5-2)
   e. **Live Load Punching Shear (V_{LL})** – This section calculates the live load punching shear generated by the various trucks being considered. These calculations do not include impact.
      i. The live load punching shear is calculated as follows:
      $V_{LL} = V / (b_o * d)$ (Eq. 5-3)

   The max tire weight used for calculating punching shear for each truck is as follows:

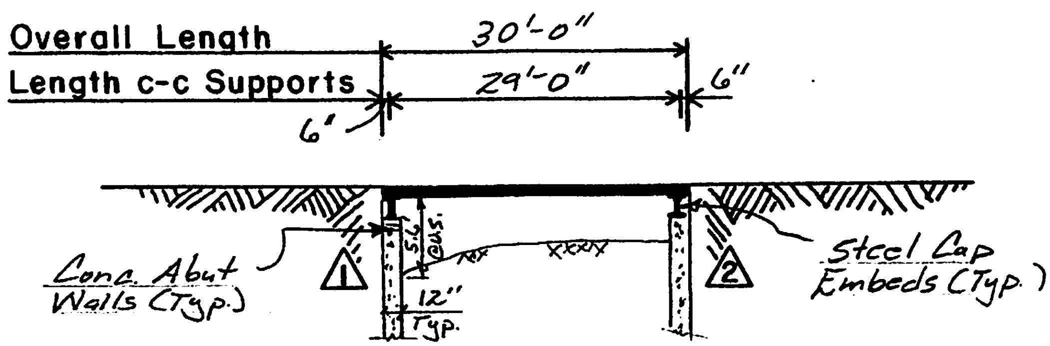
H Truck	16.00 kips
HS Truck	16.00 kips
SU4 Truck	8.50 kips
SU5 Truck	8.50 kips
SU6 Truck	8.50 kips
SU7 Truck	8.50 kips
EV2 Truck	16.75 kips
EV3 Truck	15.50 kips
Type 3 Truck	8.50 kips
Type 3-S2 Truck	7.75 kips
Type 3-3 Truck	8.00 kips
Notional Rating Load Truck	8.50 kips

General Notes:

- Per the engineer's discretion, reference Section 6.1.5.1-Decks in the Manual For Bridge Evaluation, 3rd Edition:

"Stringer-supported concrete deck slabs and metal decks that are carrying normal traffic satisfactorily need not be routinely evaluated for load capacity."

District 16 County 013 Cont.-Sec. AA01-91 Structure 001 Route Central Ln.



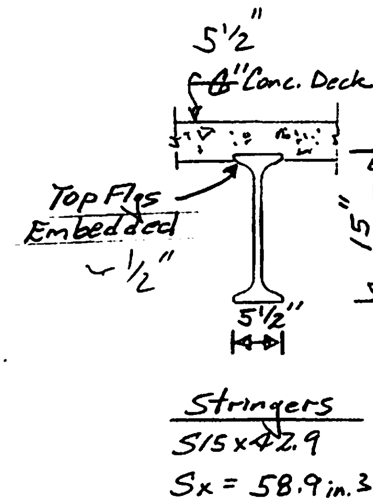
SIDE VIEW

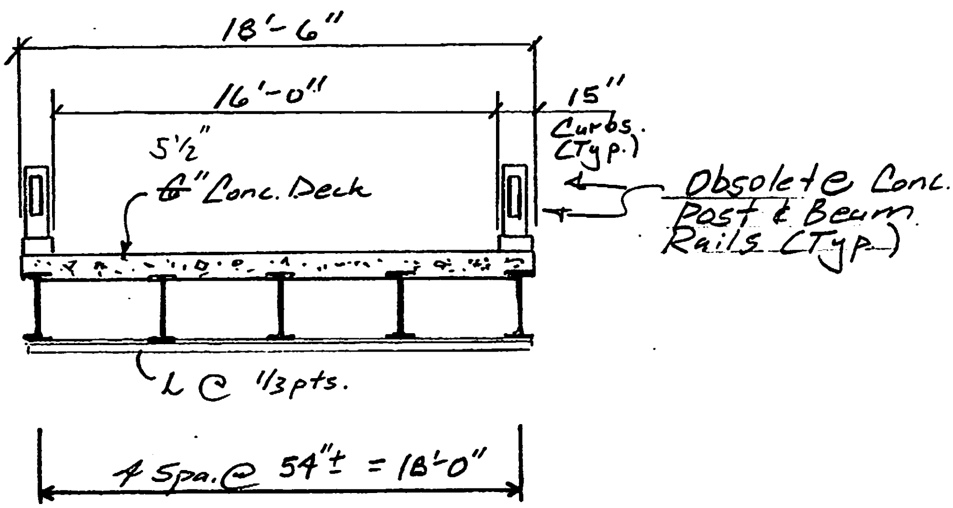
(Looking South)

LEGEND

○ Span Numbers

△ Abutment Numbers





SPAN 1

TBLRP-LFR Spreadsheet

Concrete Deck without Plans

Rating must be performed if concrete deck is <6” thick or the condition rating is 4 or less.

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Corpus Christi (16)
County:	Bee (013)
Structure # :	AA01-91-001
Location:	Central Lane Over Waterway

AADT ®:	50	**# of Lanes:**	1
Truck % (1% MIN):	1%		
EV Daily Crossing:	1	**(1 or 10)** One Direction	
Year Built:	2005		
Deck Descr:	5.5" Concrete Deck		

Deck Inputs

DATA INPUT TABLE	
Deck Condition Rating:	7
Deck Thickness (in):	5.500
Assumed Eff. Deck Thickness (d) (in):	5.500
f'c (ksi):	2.5
LL Impact:	1.30

RECOMMENDED f'c OF CONCRETE DECK		
Good	2.5	ksi
Fair	1.5	ksi
Poor	1.0	ksi

TIRE CONTACT AREA		
Length (c1):	10.000	in
Width (c2):	20.000	in
βc:	2	

DEAD LOAD INPUTS	
Wearing Surface Thickness (in):	0.000
Wearing Surface Material Unit Weight (kcf):	0.000
Fill Material Depth (in):	0.000
Fill Material Unit Weight (kcf):	0.000
Misc. Dead Load (ksf):	0.061

Punching Shear Analysis

Concrete Deck Shear Capactiy (V_c)

$V_c = (.8 + 2 / \beta_c) * \sqrt{f'_c} < 1.8 * \sqrt{f'_c}$

0.090 *ksi*

Punching Shear Perimeter (b_o):

$b_o = 2 * (c_1 + c_2) + 4 * d$

82.000 *in*

Live Load Punching Shear (V_{LL})

$V_{LL} = V / (b_o * d)$

Truck	Max Tire Weight (V) (k)	V_{LL} w/o impact (ksi)
H:	16.00	0.035
HS:	16.00	0.035
SU_4:	8.50	0.019
SU_5:	8.50	0.019
SU6:	8.50	0.019
SU_7:	8.50	0.019
T_3:	8.50	0.019
T3S2:	7.75	0.017
T3-3:	8.00	0.018
NRL:	8.50	0.019
EV_2:	16.75	0.037
EV_3:	15.50	0.034

Additional Notes

Year, Bridge Condition, and Traffic Values assumed.
Waterway Unknown.

Curb Load: 2 x 15in x 36in x 0.150 kcf x (1 ft^2 / 144in) / (18.5ft)
Misc. Dead Load = 0.061 k/ft^2

€ - Punching Shear Controls Ratings
¥ - Based on H-20 Rating
£ - Punching Shear Controls Ratings

€ HS Ratings			
HS Inventory:	HS 18.0	RF= 0.90	
HS Operating:	HS 30.0	RF= 1.50	
¥£ H RATING			
H Inventory:	H 18.0	RF= 0.90	
H Operating:	H 30.0	RF= 1.50	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	2.83	**TYPE 3:**	2.83
SU_5 Operating:	2.83	**TYPE 3S2:**	3.10
SU_6 Operating:	2.83	**TYPE 3-3:**	3.00
SU_7 Operating:	2.83	**NRL:**	2.83
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.43	**EV_3 Operating:**	1.55

See Formula 6-1a (MCEB) for the general Rating Formula.

Concrete Deck

	Concrete Unit Weight:	0.150 kcf
(Because this is less than 6", punching shear analysis is required) >>>	Deck Thickness:	5.500 in
	Concrete Deck (Item 58) Condition Rating:	7
	Assumed Eff. Deck Thickness, d:	5.500 in
	f'_c:	2.5 ksi
	LL Impact:	1.30
	Length, c1:	10.000 in
	Width, c2:	20.000 in
	β_c = Width / Length = 20 in / 10 in:	2

Punching Shear Analysis Calculations

Concrete Deck Shear Capacity, V_c =	$(.8 + 2 / \beta_c) * \sqrt{f'_c} < 1.8 * \sqrt{f'_c}$	
Concrete Deck Shear Capacity, V_c =	(0.8+2/2) * √(2.5*1000)/1000 < 1.8 * √(2.5*1000)/1000 =	0.090 ksi
Punching Shear Perimeter, b_o =	2 * (c1 + c2) + 4 * d	
Punching Shear Perimeter, b_o =	2 * (10.000 + 20.000) + 4 * 5.500 in =	82.000 in
Live Load Punch Shear, V_{LL} = Max Tire Weight / (Punching Shear Perimeter * Assumed Eff. Deck Thickness)		
V_{LL} (H-20) =	16.00 k / (82.000 in * 5.500 in) =	0.035 ksi
V_{LL} (HS-20) =	16.00 k / (82.000 in * 5.500 in) =	0.035 ksi
V_{LL} (SU4) =	8.50 k / (82.000 in * 5.500 in) =	0.019 ksi
V_{LL} (SU5) =	8.50 k / (82.000 in * 5.500 in) =	0.019 ksi
V_{LL} (SU6) =	8.50 k / (82.000 in * 5.500 in) =	0.019 ksi
V_{LL} (SU7) =	8.50 k / (82.000 in * 5.500 in) =	0.019 ksi
V_{LL} (EV2) =	16.75 k / (82.000 in * 5.500 in) =	0.037 ksi
V_{LL} (EV3) =	15.50 k / (82.000 in * 5.500 in) =	0.034 ksi
VLL (T3) =	8.50 k / (82.000 in * 5.500 in) =	0.019 ksi
V_{LL} (T3S2) =	7.75 k / (82.000 in * 5.500 in) =	0.017 ksi
V_{LL} (T3-3) =	8.00 k / (82.000 in * 5.500 in) =	0.018 ksi
V_{LL} (NRL) =	8.50 k / (82.000 in * 5.500 in) =	0.019 ksi
H (Inventory Rating) =	36 * [V_c / ((A2-Inv) * V_{LL} * LL Impact Factor)] / (36/20)	
H (Inventory Rating) =	36 * [0.090 ksi / (2.17 * 0.035 * 1.3)] / (36/20) =	H 18.0
H (Operating Rating) =	36 * [V_c / ((A2-Opr) * V_{LL} * LL Impact Factor)] / (36/20)	
H (Operating Rating) =	36 * [0.090 ksi / (1.3 * 0.035 * 1.3)] / (36/20) =	H 30.0
HS (Inventory Rating) =	36 * [V_c / ((A2-Inv) * V_{LL} * LL Impact Factor)] / (36/20)	
HS (Inventory Rating) =	36 * [0.090 ksi / (2.17 * 0.035 * 1.3)] / (36/20) =	**H 18.0 <<<**
HS (Operating Rating) =	36 * [V_c / ((A2-Opr) * V_{LL} * LL Impact Factor)] / (36/20)	
HS (Operating Rating) =	36 * [0.090 ksi / (1.3 * 0.035 * 1.3)] / (36/20) =	**H 30.0 <<<**

Note: Values above are rounded (not all decimals shown).

Section 6: Steel Corrugated Deck

1. **DATA INPUT TABLE**
    a. ***Deck Type*** – Select Steel Corrugated Deck from the dropdown.
    b. ***Designation*** – Either select a corrugated deck designation from the dropdown or enter a new designation name.
        i. Selecting a designation from the dropdown will fill in the Original Thickness, Weight, and Original Section Modulus of the deck.
        ii. The table referenced for the deck designation dropdown can be found to the right of the printed area.
    c. ***F_y (ksi)*** – Input the yield stress of the corrugated deck. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.
    d. ***Original Thickness (in)*** – Enter the original corrugated steel deck metal thickness.
    e. ***Weight (ksf)*** – Enter the weight of just the corrugated steel deck. This will need to be calculated if no standard designation is selected from the dropdown.
    f. ***Original S_x (in^3/ft)*** – Enter the original elastic section modulus (S_x) per foot of the corrugated steel deck. The S_x will be adjusted for a reduced section based on the *Section Loss (%)* input. This will need to be calculated if no standard designation is selected from the dropdown.
    g. ***Section Loss (%)*** – Enter the section loss percentage for the metal corrugated steel deck thickness.
    h. ***Simple or Continuous*** – Select whether the corrugated deck is simple or continuous over the superstructure's stringers.
    i. ***Fill Depth Above Top of Deck (in)*** – Input the depth of fill atop the deck that is used for dead load calculations.
    j. ***Fill Material*** – Input the fill material type (i.e. Dirt, Gravel, Asphalt, etc.).
    k. ***Fill Material Unit Weight (kcf)*** – Input the unit weight of the fill material used for dead load calculations.
    l. ***Misc. Dead Load (ksf)*** – Input any additional weight (in kips per square feet) acting on the deck used for dead load calculations.
2. **DATA FOR LIVE LOAD DISTRIBUTION**
    a. ***Stringer Spacing (in)*** – Input the stringer spacing, center-to-center.
    b. ***Flange Width (in)*** – Input the stringer top flange width.
    c. ***Calculated Deck Span Between Flange Tips (in)*** – This cell subtracts the top flange width from the Stringer Spacing to generate the distance between each top flanges' tips.
    d. ***Calculated Deck Span (in)*** – This cell subtracts 1/4 of adjacent top flange's width from the stringer spacing, generating the span distance used for positive moment analysis.
    e. ***LL Impact Factor*** – Input the live load impact factor to be used for the deck.
        i. 1.3 is a standard impact factor for most load rating scenarios.
        ii. This value should be adjusted at the Engineer's discretion.

3. **TIRE CONTACT AREA**
    a. The tire contact area is calculated per AASHTO 3.30 and distributed through the fill depth above top of deck at 45° angle in each direction.
4. **TIRE CONTACT AREA OVERRIDE**
    a. A tire width and length for both the rear and front axles is provided for unique cases where the geometry or condition of the deck may dictate using a different tire contact area than what AASHTO 3.30 specifies.
    b. These values should be input at the Engineer's discretion.
5. **Analysis**
    a. ***Deck Capacity (C_u)*** – Calculated as the F_y*S_x*(1-SL%) in units of k-in/in.
    b. ***Dead Load Moments***
        i. Displays the controlling moment formula based on the Simple/Continuous input.
            1. 0.125*w*L^2 for positive moment simple span analysis
            2. 0.08*w*L^2 for positive moment continuous span analysis
                a. 0.08 was selected based on available beam diagrams for continuous spans.
        ii. The calculated moment is shown for the following:
            1. ***Steel Corrugated Deck*** – Using the *Weight (ksf)* input to calculate w.
            2. ***Fill*** – Using *the Fill Depth Above Top of Deck (in) and Fill Material Unit Weight (kcf)* inputs to calculate w.
            3. ***Miscellaneous*** – Using the *Misc. Dead Load (ksf)* input to calculate w.

c. ***Live Load Moments***

i. Displays the calculated positive moment for each rated truck. Both the rear and front axles are analyzed. Even though the front axle is typically much lighter, the smaller contact area will cause it to control in some cases.

ii. Positive moments are calculated by determining if the tire contact area is wider than the stringer spacing.

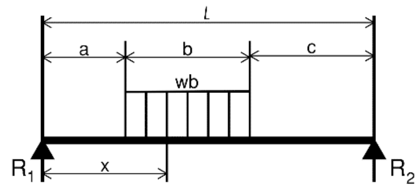
1. If tire width < stringer spacing
    a. $Mu = R_1*(a+(R_1/2w))$
    b. 

Figure 1: Simple Beam - Uniform Load Partially Distributed

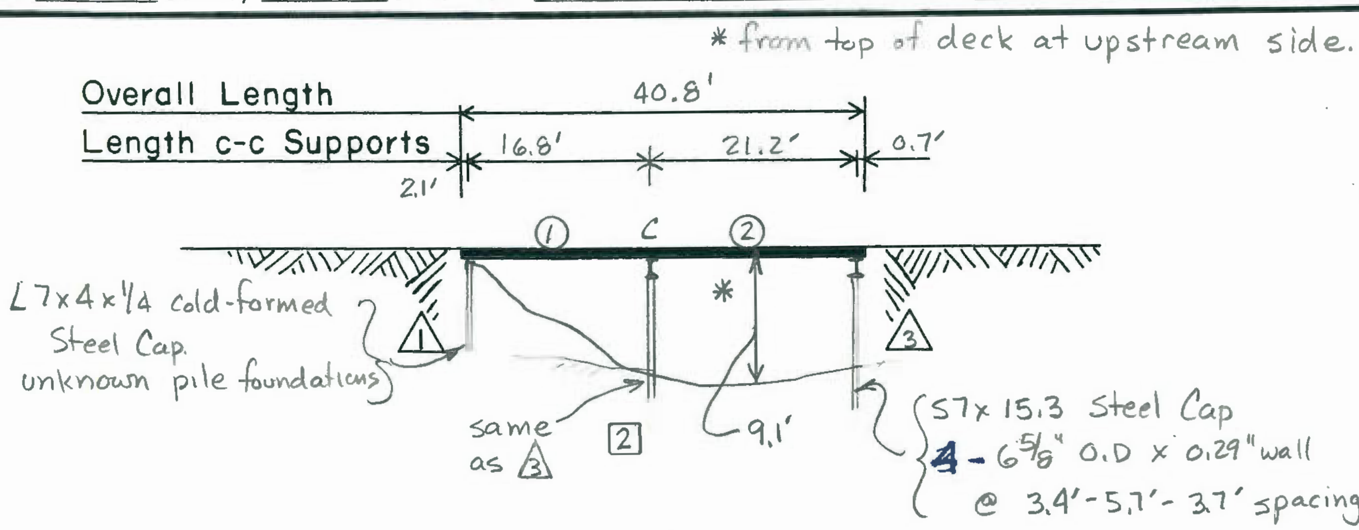
2. If tire width > stringer spacing
    a. $Mu = 0.125*w*L^2$ for positive moment simple span analysis
    b. $Mu = 0.08*w*L^2$ for positive moment continuous span analysis
        i. 0.08 was selected based on available beam diagrams for continuous spans.
3. Ratings are calculated based on Formula 6-1a (MCEB)
    a. $RF = [C_u-(1.3*DL)]/(A*LL)$ (Eq. 6-1, MCEB Formula 6-1a)
4. Additional information on the analysis can be found to the right of the printed area.

General Notes:

- Per the engineer's discretion, reference Section 6.1.5.1-Decks in the Manual For Bridge Evaluation, 3rd Edition:

"Stringer-supported concrete deck slabs and metal decks that are carrying normal traffic satisfactorily need not be routinely evaluated for load capacity."

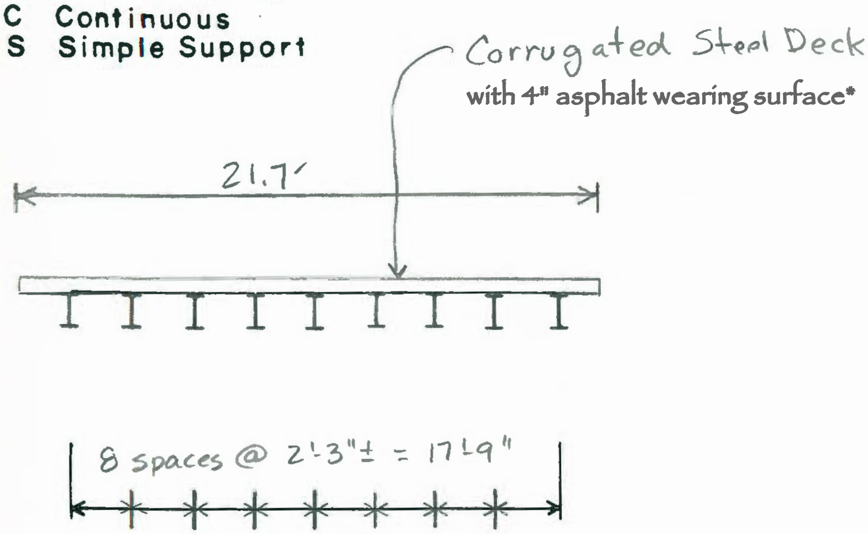
District 01 County 060 Cont.-Sec. AA0113 Structure 001 Route CR 3440



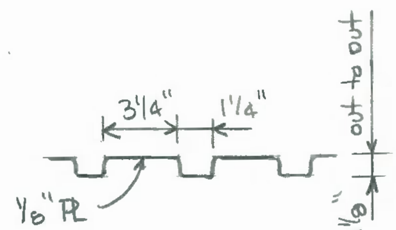
SIDE VIEW
(Looking NORTH)

LEGEND

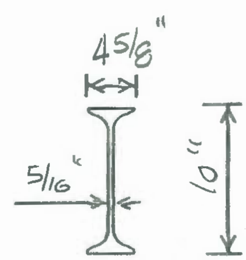
- ○ Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support



SPANS 1 & 2



Corrugated Steel Deck



STRINGERS
S10 x 25.4

SPAN

*4" asphalt wearing surface was added to this bridge for use as example only.

TBLRP-LFR Spreadsheet

Steel Deck

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Paris (01)	**AADT ®:**	50
County:	Delta (060)	**# of Lanes:**	1
Structure # :	AA01-13-001	**Truck % (1% MIN):**	1%
Location:	CR 3340 Over Jennings Creek	**EV Daily Crossing:**	1 **(1 or 10)** One Direction
		Year Built:	1945
		Deck Descr:	4-1/2" x 1-1/8" x 1/8" Corr Deck w/ Asphalt

Deck Inputs

DATA INPUT TABLE	
Deck Type	Steel Corrugated Deck
Designation:	4.5 x 1.125 x 0.125
Fy (ksi):	36.0
*Original Thickness (in):	0.125
Weight (ksf):	0.006
Original Sx (in^3/ft):	0.446
Section Loss (%):	0%
Simple or Continuous:	Continuous
Fill and Wearing Surface Depth (in):	4.000
Fill and Wearing Surface Material:	Asphalt
Fill and Wearing Surface Unit Weight (kcf):	0.145
Misc. Dead Load (ksf):	0.000

*Get designated section properties from the table when applicable.

TIRE CONTACT AREA (in)**			
Rear	***AASHTO***	***Through Fill***	***Total***
Width	20.000	8.000	28.000
Length	10.000	8.000	18.000
Front	***AASHTO***	***Through Fill***	***Total***
Width	10.000	8.000	18.000
Length	10.000	8.000	18.000

DATA FOR LIVE LOAD DISTRIBUTION	
Stringer Spacing (in):	27.000
Flange Width (in):	4.600
Calculated Deck Span Between Flange Tips (in):	22.400
Calculated Deck Span (in):	24.700
LL Impact Factor:	1.30

TIRE CONTACT AREA OVERRIDE (in)		
	Width	Length
All Trucks Rear		
All Trucks Front		

**Tire contact areas referenced in AASHTO 3.30

Analysis

Deck Capacity (C_u)

$C_u = F_y * S_x * (1-SL\%)$

Cu = 36 * 0.446 * (1-0) = 1.338 k-in/in

Dead Load Moments	Continuous +Mmax = 0.08*w*l^2
Steel Corrugated Deck:	0.002 k-in/in
Fill:	0.020 k-in/in
Miscellaneous:	0.000 k-in/in
Total:	0.022 k-in/in

Live Load Moments

M_{LL} HS:	2.378 k-in/in
M_{LL} H:	2.378 k-in/in
M_{LL} SHV_{SU4}:	1.308 k-in/in
M_{LL} SHV_{SU5}:	1.308 k-in/in
M_{LL} SHV_{SU6}:	1.308 k-in/in
M_{LL} SHV_{SU7}:	1.308 k-in/in
M_{LL} T3:	1.744 k-in/in
M_{LL} T3S2:	1.152 k-in/in
M_{LL} T3-3:	1.308 k-in/in
M_{LL} NRL:	1.308 k-in/in
M_{LL} EV_2:	2.617 k-in/in
M_{LL} EV_3:	2.617 k-in/in

Additional Notes

€ - Flexure Controls Rating
¥ - Based on H-20 Rating
£ - Flexure Controls Rating

€ HS Ratings			
HS Inventory:	HS 03.9	RF= 0.20	
HS Operating:	HS 06.5	RF= 0.33	
¥£ H RATING			
H Inventory:	H 03.9	RF= 0.20	
H Operating:	H 06.5	RF= 0.33	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	0.59	**TYPE 3:**	0.44
SU_5 Operating:	0.59	**TYPE 3S2:**	0.67
SU_6 Operating:	0.59	**TYPE 3-3:**	0.59
SU_7 Operating:	0.59	**NRL:**	0.59
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	0.30	**EV_3 Operating:**	0.30

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Corrugated Deck

Inputs

			Designation:	4.5 x 1.125 x 0.125
Stringer Spacing:	27.000 in		F_y:	36.0 ksi
Flange Width:	4.600 in		*Original Thickness:	0.125 in
			Weight:	0.006 ksf
Calculated Deck Span Between Flange Tips = Stringer Spacing - Flange Width			Original S_x:	0.446 in^3/ft
Calculated Deck Span Between Flange Tips:	22.400 in		Section Loss:	0 %
			Simple or Continuous:	Continuous
Calculated Deck Span = Stringer Spacing - Flange Width / 2			Fill Depth Above Top of Deck:	4.000 in
Calculated Deck Span:	24.700 in		Fill Material:	Asphalt
			Fill Material Unit Weight:	0.145 kcf
LL Impact Factor:	1.30		Misc. Dead Load:	0.000 ksf

Capacity

C_u = F_y*S*(1-SL%) = 36.0 ksi * 0.446 in^3/ft * (1ft / 12 in) * (1 - 0) = 1.338 k-in/in

Dead Load Moments

Dead load moments are calculated based on beam diagram tables for distributed loads on simple/continuous spans. The following equations are used:

Simple max (+)M	$0.125*w*l^2$	
Continuous max (+)M	$0.08*w*l^2$	<<< Selected in Example

Corrugated Deck M_{DL} =	0.08 * 0.006 ksf * (1 ft^2 / 144 in^2) * $(27.000\ in)^2$	=	0.002 k-in/in
Fill Material M_{DL} =	0.08 * [(4.000 in / 12 in) * 0.145 kcf)] * (1 ft^2 / 144 in^2) * $(27.000\ in)^2$	=	0.020 k-in/in
Misc. Loads M_{DL} =	0.08 * (0.000 ksf) * (1 ft^2 / 144 in^2) * $(27.000\ in)^2$	=	0.000 k-in/in
	Total	=	0.022 k-in/in

Live Load Moments

Assuming that the wheel width will be less than the girder spacing, moments will be calculated based on a simple beam with a uniform load partially distributed. (Mu = R1*(a+(R1/2w))). In cases where the loaded width is larger than the girder spacing, $0.125*w*l^2$ will be used for simple span and $0.100*w*l^2$ for continuous spans.

Tire contact area		2 * fill depth (in)	Total Tire Load Area
Width =	20.000 in	8.000 in	28.000 in
Length =	10.000 in	8.000 in	18.000 in

HS Truck Axle		=	16 k
Distributed load to top of deck =	16 k / 28.000 in	=	0.571 k-in/in
Wheel Load (R1) =	16 k / 2	=	8 k
Distance from CL stringer to Edge of Tire Load Area (a) =	(24.700 in - 28.000 in) / 2	=	-1.650 in
(+)M from beam diagrams =	(8 k * (-1.65 in + 8 k / (2 * 0.571 k-in/in))) / 18.000 in	=	2.378 k-in/in

Front Axle

Tire contact area		2 * fill depth (in)	Total Tire Load Area
Width =	10.000 in	8.000 in	18.000 in
Length =	10.000 in	8.000 in	18.000 in

HS Truck Axle		=	4 k
Distributed load to top of deck =	4 k / 18.000 in	=	0.222 k-in/in
Wheel Load (R1) =	4 k / 2	=	2 k
Distance from CL stringer to Edge of Tire Load Area (a) =	(24.700 in - 18.000 in) / 2	=	3.350 in
(+)M from beam diagrams =	(2 k * (3.35 in + 2 k / (2 * 0.222 k-in/in))) / 18.000 in	=	0.872 k-in/in

Rating Factors

HS-20 INV RF =	(1.338 - (1.3 * 0.022))/(2.17 * 2.378 * 1.3)	=	0.20
			HS 3.9 <<<
HS-20 OPR RF =	(1.338 - (1.3 * 0.022))/(1.3 * 2.378 * 1.3)	=	0.33
			HS 6.5 <<<

Note: Values above are rounded (not all decimals shown).

Section 7: Steel Plate Deck

1. **DATA INPUT TABLE**
    a. ***Deck Type*** – Select Steel Plate Deck from the dropdown.
    b. ***F_y (ksi)*** – Input the yield stress of the steel plate deck. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.
    c. ***Original Thickness (in)*** – Enter the steel plate thickness.
    d. ***Original Weight (ksf)*** – The weight of the steel plate deck based on the thickness entered is calculated, but can be overwritten.
        i. [Thickness (ft) x 0.49 k/ft^3]
    e. ***Original Sx (in^3/ft)*** – The section modulus (S_x) per foot of the steel plate deck is based on the thickness entered and calculated automatically. This value can be overwritten if necessary. [2 x (Thickness (in))^2] (in^3/ft strip)
    f. ***Section Loss (%)*** – Enter the section loss percentage of the steel plate thickness.
    g. ***Simple or Continuous*** – Select whether the steel plate is simple or continuous over the superstructure's stringers.
    h. ***Fill Depth Above Top of Deck (in)*** – Input the depth of fill atop the deck that is used for dead load calculations.
    i. ***Fill Material*** – Input the fill material type (i.e. Dirt, Gravel, Asphalt, etc.)
    j. ***Fill Material Unit Weight (kcf)*** – Input the unit weight of the fill material used for dead load calculations.
    k. ***Misc. Dead Load (ksf)*** – Input any additional weight (in kips per square feet) acting on the deck that will be used for dead load calculations.
2. **DATA FOR LIVE LOAD DISTRIBUTION**
    a. ***Stringer Spacing (in)*** – Input the stringer spacing, center-to-center.
    b. ***Flange Width (in)*** – Input the stringer top flange width.
    c. ***Calculated Deck Span Between Flange Tips (in)*** – This cell subtracts the top flange width from the Stringer Spacing to generate the distance between each top flanges' tips.
    d. ***Calculated Deck Span (in)*** – This cell subtracts 1/4 of adjacent top flange's width from the stringer spacing, generating the span distance used for positive moment analysis.
    e. ***LL Impact Factor*** – Input the live load impact factor to be used for the deck.
        i. 1.3 is a standard impact factor for most load rating scenarios.
        ii. This value should be adjusted at the Engineer's discretion.
3. **TIRE CONTACT AREA**
    a. The tire contact area is calculated per AASHTO 10.41.2 and distributed through the fill depth above top of deck at 45° angle in each direction.
4. **TIRE CONTACT AREA OVERRIDE**
    a. A tire width and length for the both the rear and front axles is provided for unique cases where the geometry or condition of the deck may dictate using a different tire contact area than what AASHTO 10.41.2 specifies.
    b. These values should be input at the Engineer's discretion.

5. **Analysis**
    a. ***Deck Capacity (C_u)*** – Calculated as the F_y*S_x*(1-SL%) in units of k-in/in.
    b. ***Dead Load Moments***
        i. Displays the controlling moment formula based on the Simple/Continuous input.
            1. 0.125*w*L^2 for positive moment simple span analysis
            2. 0.08*w*L^2 for positive moment continuous span analysis
                a. 0.08 was selected based on available beam diagrams for continuous spans.
        ii. The calculated moment is shown for the following:
            1. ***Steel Plate Deck*** – Using the *Original Weight (ksf)* input to calculate w.
            2. ***Fill*** – Using *the Fill Depth Above Top of Deck (in) and Fill Material Unit Weight (kcf)* inputs to calculate w.
            3. ***Miscellaneous*** – Using the *Misc. Dead Load (ksf)* input to calculate w.
    c. ***Live Load Moments***
        i. Presents the calculated positive moment for each rated truck. Both the rear and front axles are analyzed. Even though the front axle is typically much lighter, the smaller contact area will cause it to control in some cases.
        ii. Positive moments are calculated by determining if the tire contact area is wider than the stringer spacing.
            1. If tire width < stringer spacing
                a. Mu = R_1*(a+(R_1/2*w))
                b. See *Figure 1: Simple Beam - Uniform Load Partially Distributed* in the Steel Corrugated Deck Section.
            2. If tire width > stringer spacing
                a. Mu = 0.125*w*L^2 for positive moment simple span analysis.
                b. Mu = 0.08*w*L^2 for positive moment continuous span analysis.
                    i. 0.08 was selected based on available beam diagrams for continuous spans.
    d. Ratings are calculated based on Formula 6-1a (MCEB)
        i. RF = [C_u-(1.3*DL)]/(A*LL) (Eq. 7-1, MCEB Formula 6-1a)
    e. Additional information on the analysis can be found to the right of the printed area.

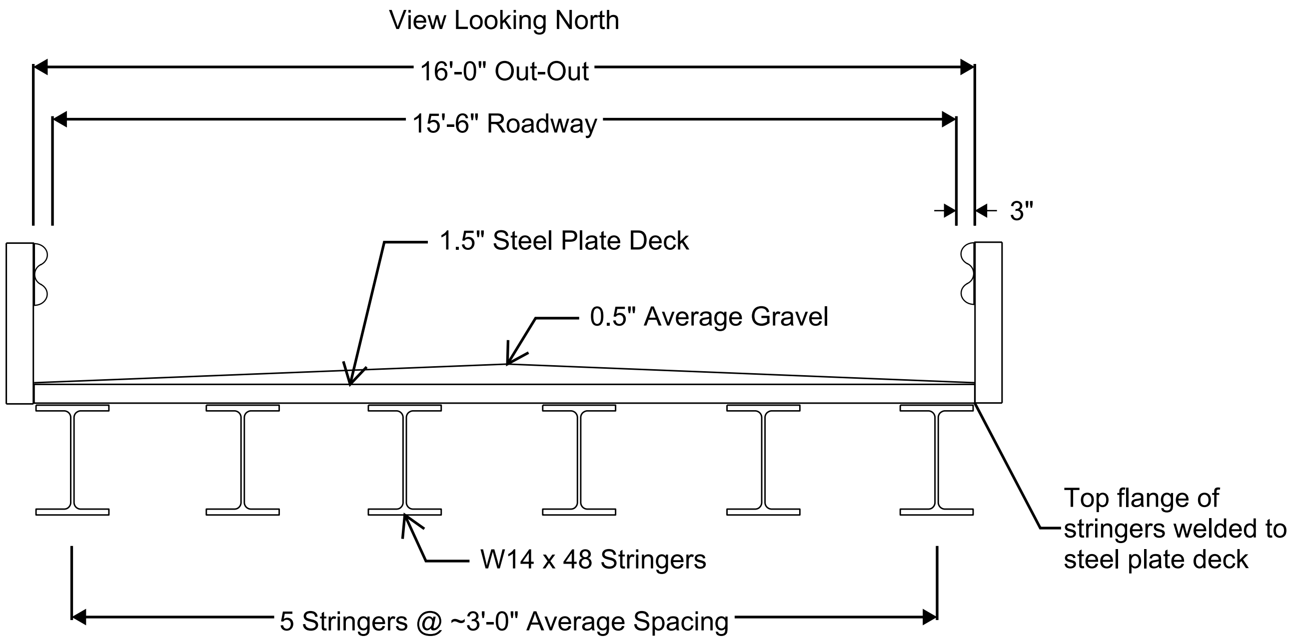
General Notes:

- Per the engineer's discretion, reference Section 6.1.5.1-Decks in the Manual For Bridge Evaluation, 3rd Edition:

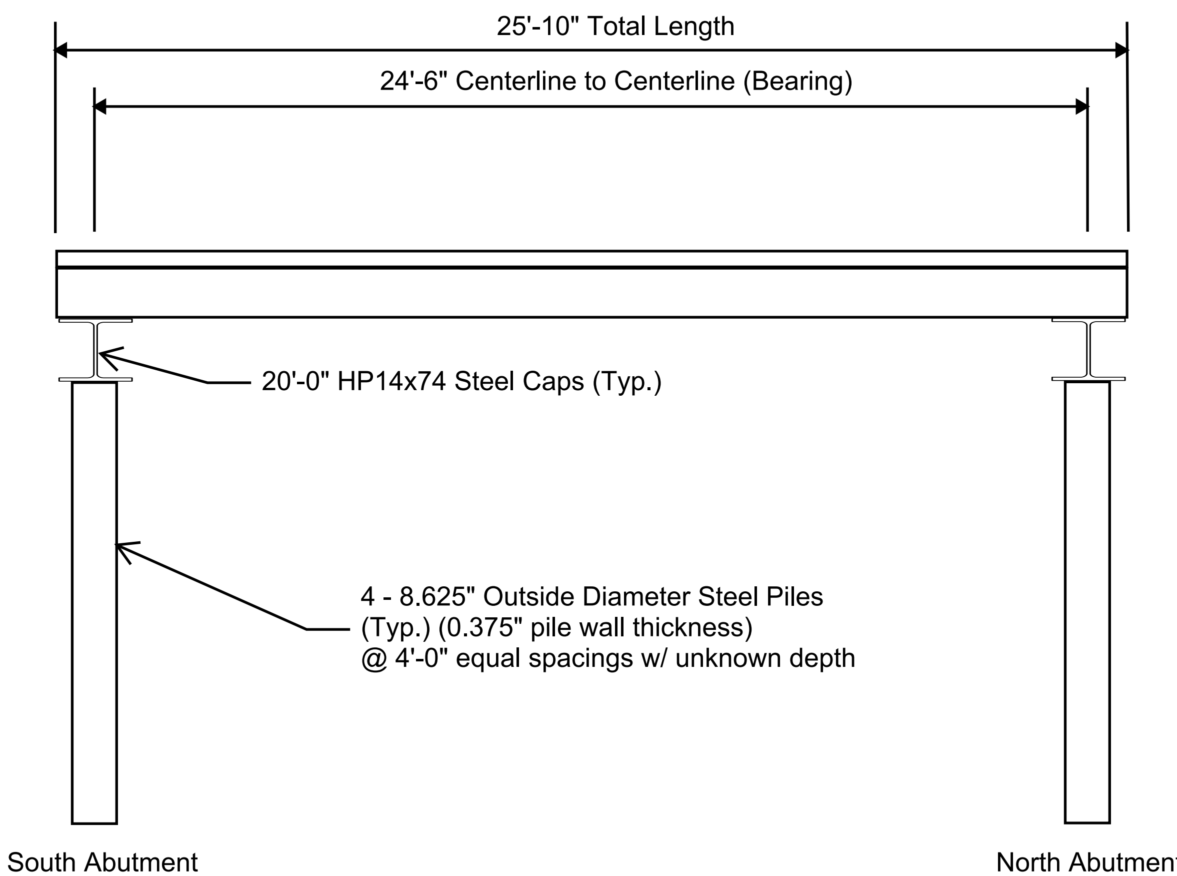
"Stringer-supported concrete deck slabs and metal decks that are carrying normal traffic satisfactorily need not be routinely evaluated for load capacity."

Below sketch for example purposes only.

District XX County XXX Con. Sec. XXXX-XX Structure XXX Route Roadway Feature Crossed Stream



Notes:
Deck and Stringers are 50 ksi steel
Caps are 36 ksi steel
Piles are 35 ksi steel
Minor pitting in steel plate decking



TBLRP-LFR Spreadsheet

Steel Deck

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Tyler (10)	AADT ®:	50	# of Lanes:	1
County:	Anderson (001)	Truck % (1% MIN):	1%		
Structure # :	XXXX-XX-XXX	EV Daily Crossing:	1	(1 or 10)	One Direction
Location:	Roadway Over Stream	Year Built:	2005		
		Deck Descr:	3/2" Steel Plate Deck w/ 1/2" Gravel		

Deck Inputs

DATA INPUT TABLE	
Deck Type	Steel Plate Deck
Fy (ksi):	50.0
*Original Thickness (in):	1.500
Original Weight (ksf):	0.061
Original Sx (in^3/ft):	4.500
Section Loss (%):	10%
Simple or Continuous:	Continuous
Fill and Wearing Surface Depth (in):	0.500
Fill and Wearing Surface Material:	Gravel
Fill and Wearing Surface Unit Weight (kcf):	0.120
Misc. Dead Load (ksf):	0.005

*Get designated section properties from the table when applicable.

TIRE CONTACT AREA (in)**			
Rear	*AASHTO*	*Through Fill*	*Total*
HS Width	24.000	1.000	25.000
SHV/EV Width	20.000	1.000	21.000
Length	10.000	1.000	11.000
Front	*AASHTO*	*Through Fill*	*Total*
Width	10.000	1.000	11.000
Length	10.000	1.000	11.000

DATA FOR LIVE LOAD DISTRIBUTION	
Stringer Spacing (in):	36.000
Flange Width (in):	8.000
Calculated Deck Span Between Flange Tips (in):	28.000
Calculated Deck Span (in):	32.000
LL Impact Factor:	1.30

TIRE CONTACT AREA OVERRIDE (in)		
	Width	Length
All Trucks Rear		
All Trucks Front		

**Tire contact areas referenced in AASHTO 10.41.2

Analysis

Deck Capacity (C_u)

$C_u = F_y{*}S_x{*}(1\text{-}SL\%)$

Cu = 50 * 4.5 * (1-0.1) = 16.875 k-in/in

Dead Load Moments	Continuous +Mmax = 0.08*w*l^2
Steel Plate Deck:	0.044 k-in/in
Fill:	0.004 k-in/in
Miscellaneous:	0.004 k-in/in
Total:	0.051 k-in/in

Live Load Moments	
M_{LL} HS:	7.091 k-in/in
M_{LL} H:	7.091 k-in/in
M_{LL} SHV_{SU4}:	4.153 k-in/in
M_{LL} SHV_{SU5}:	4.153 k-in/in
M_{LL} SHV_{SU6}:	4.153 k-in/in
M_{LL} SHV_{SU7}:	4.153 k-in/in
M_{LL} T3:	4.818 k-in/in
M_{LL} T3S2:	3.787 k-in/in
M_{LL} T3-3:	3.909 k-in/in
M_{LL} NRL:	4.153 k-in/in
M_{LL} EV_2:	7.423 k-in/in
M_{LL} EV_3:	7.227 k-in/in

Additional Notes

90% section remaining due to noted pitting.
0.005 ksf added to deck dead loads for bridge railings.

€ - Flexure Controls Rating
¥ - Based on H-20 Rating
£ - Flexure Controls Rating

€ HS Ratings		
HS Inventory:	HS 16.8	RF= 0.84
HS Operating:	HS 28.1	RF= 1.40
¥£ H RATING		
H Inventory:	H 16.8	RF= 0.84
H Operating:	H 28.1	RF= 1.40

AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	2.39	TYPE 3:	2.06
SU_5 Operating:	2.39	TYPE 3S2:	2.63
SU_6 Operating:	2.39	TYPE 3-3:	2.54
SU_7 Operating:	2.39	NRL:	2.39
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.34	EV_3 Operating:	1.38

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Plate Deck

Inputs

Stringer Spacing:	36.000 in	F_y:	50.0 ksi
Flange Width:	8.000 in	*Original Thickness:	1.500 in
		Weight:	0.061 ksf
		Original S_x:	4.500 in^3/ft
Calculated Deck Span Between Flange Tips = Stringer Spacing - Flange Width		Section Loss:	10 %
Calculated Deck Span Between Flange Tips:	28.000 in	Simple or Continuous:	Continuous
		Fill Depth Above Top of Deck:	0.500 in
Calculated Deck Span = Stringer Spacing - Flange Width / 2		Fill Material:	Gravel
Calculated Deck Span:	32.000 in	Fill Material Unit Weight:	0.120 kcf
		Misc. Dead Load:	0.005 ksf
LL Impact Factor:	1.30		

Capacity

C_u = F_y*S*(1-SL%) = 50.0 ksi * 4.500 in^3/ft * (1ft / 12 in) * (1 - 0.10) = 16.875 k-in/in

Dead Load Moments

Dead load moments are calculated based on beam diagram tables for distributed loads on simple/continuous spans. The following equations are used:

Simple max (+)M $0.125*w*l^2$

Continuous max (+)M $0.08*w*l^2$ <<< Selected in Example

Steel Plate Deck M_{DL} =	0.08 * 0.061 ksf * (1 ft^2 / 144 in^2) * $(36.000\ in)^2$	=	0.044 k-in/in
Fill Material M_{DL} =	0.08 * [(0.500 in / 12 in) * 0.120 kcf)] * (1 ft^2 / 144 in^2) * $(36.000\ in)^2$	=	0.004 k-in/in
Misc. Loads M_{DL} =	0.08 * (0.005 ksf) * (1 ft^2 / 144 in^2) * $(36.000\ in)^2$	=	0.004 k-in/in
	Total	=	0.051 k-in/in

Live Load Moments

Assuming that the wheel width will be less than the girder spacing, moments will be calculated based on a simple beam with a uniform load partially distributed. (Mu = R1*(a+(R1/2w))). In cases where the loaded width is larger than the girder spacing, $0.125*w*l^2$ will be used for simple span and $0.100*w*l^2$ for continuous spans.

	Tire contact area	2 * fill depth (in)	Total Tire Load Area
Width =	24.000 in	1.000 in	25.000 in
Length =	10.000 in	1.000 in	11.000 in

HS Truck Axle		=	16 k
Distributed load to top of deck =	16 k /25.000 in	=	0.640 k-in/in
Wheel Load (R1) =	16 k / 2	=	8 k
Distance from CL stringer to Edge of Tire Load Area (a) =	(32.000 in - 25.000 in) / 2	=	3.500 in
(+)M from beam diagrams =	(8 k * (3.5 in + 8 k / (2 * 0.640 k-in/in))) /11.000 in	=	7.091 k-in/in

Front Axle

	Tire contact area	2 * fill depth (in)	Total Tire Load Area
Width =	10.000 in	1.000 in	11.000 in
Length =	10.000 in	1.000 in	11.000 in

HS Truck Axle		=	4 k
Distributed load to top of deck =	4 k / 11.000 in	=	0.364 k-in/in
Wheel Load (R1) =	4 k / 2	=	2 k
Distance from CL stringer to Edge of Tire Load Area (a) =	(32.000 in -11.000 in) / 2	=	10.500 in
(+)M from beam diagrams =	(2 k * (10.5 in + 2 k / (2 * 0.364 k-in/in))) /11.000 in	=	2.409 k-in/in

Rating Factors

HS-20 INV RF =	(16.875 - (1.3 * 0.051))/(2.17 * 7.091 * 1.3)	=	0.84
			HS 16.8 <<<
HS-20 OPR RF =	(16.875 - (1.3 * 0.051))/(1.3 * 7.091 * 1.3)	=	1.40
			HS 28.1 <<<

Note: Values above are rounded (not all decimals shown).

Section 8: Steel Open Grid Deck

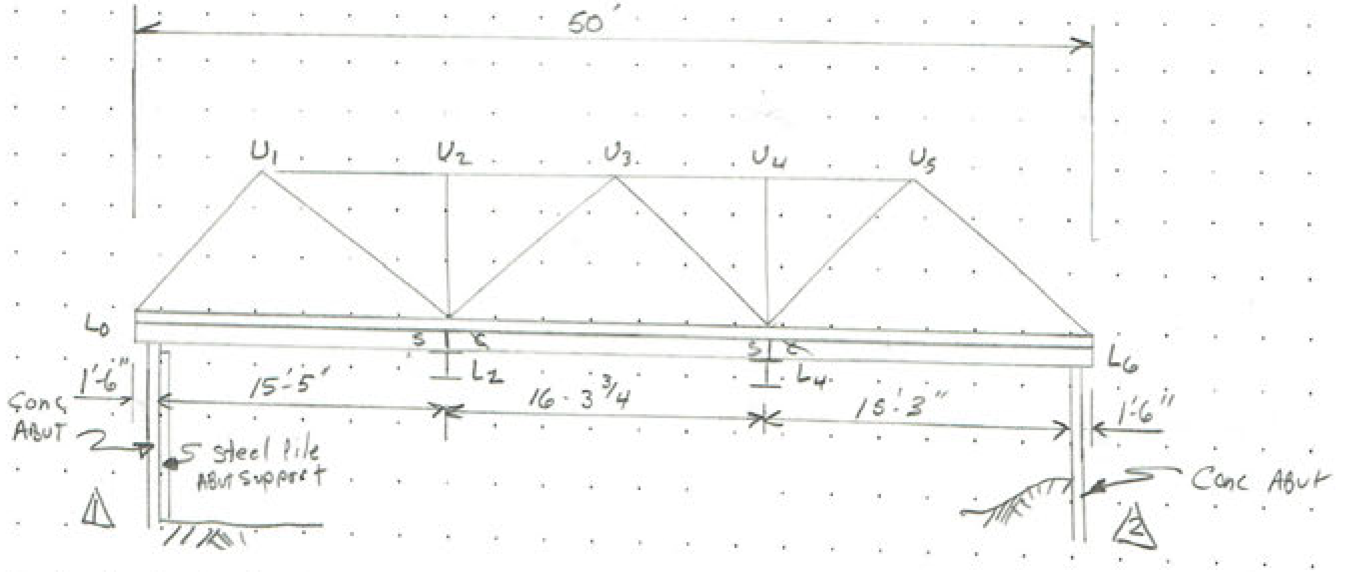
1. **DATA INPUT TABLE**
    a. ***Deck Type*** - Select Steel Open Grid Deck from the dropdown.
    b. ***Designation*** – Either select an open grid deck designation from the dropdown or enter a new designation name.
        i. Selecting a designation from the dropdown will fill in the Main Beam and Supplemental Bar dimensions as well as calculate the Total Weight and Sx.
        ii. The table referenced for the deck designation dropdown can be found to the right of the printed area.
        iii. See visuals to the right of the printed area for entering the Main and Supplemental Bar dimensions.
    c. ***Fy (ksi)*** – Input the yield stress of the open grid deck. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.
    d. ***Main Beam (MB) Depth (in)*** – Enter the main beam depth.
    e. ***Main Beam (MB) Thickness (in)*** – Enter the main beam thickness. Input is only available when Nonstandard Grid selected in Designation.
    f. ***Main Beam (MB) Spacing (in)*** – Enter the main beam spacing.
    g. ***MB Thickness Section Loss (%)*** – Enter section loss percentage (%) of the main beams.
    h. ***Supplemental Bar Depth (in)*** – Enter the supplemental bar depth.
    i. ***Supplemental Bar Thickness (in)*** – Enter the supplemental bar thickness.
    j. ***Supplement Bars Btw Each MB*** – Enter the number of supplemental bars between each main beam.
    k. ***Total Weight (ksf)*** – The total weight of the open grid deck will be calculated based on the inputs for the main beam and supplemental bars, but does not account for any additional bars. This value can be overwritten.
    l. ***Original Sx (in^3/ft)*** – The section modulus (S_x) per foot of the open grid deck will be calculated based on the inputs for the main beam and supplemental bars, but does not account for any additional bars. This value can be overwritten.
    m. ***Misc. Dead Load (ksf)*** – Enter miscellaneous dead loads that are not accounted for elsewhere. Wearing surfaces and fill are not typical on open grid decks.
2. **DATA FOR LIVE LOAD DISTRIBUTION**
    a. ***Stringer Spacing (in)*** – Input the stringer spacing, center-to-center.
    b. ***Flange Width (in)*** – Input the stringer top flange width.
    c. ***Calculated Deck Span Between Flange Tips (in)*** – This cell subtracts the top flange width from the Stringer Spacing to generate the distance between each top flanges' tips.
    d. ***Calculated Deck Span (in)*** – This cell subtracts half of the adjacent top flange's width from the stringer spacing and adds the deck thickness to this value, generating the span distance used for positive moment analysis.
    e. ***LL Impact Factor*** – Input the live load impact factor to be used for the deck.
        i. 1.3 is a standard impact factor for most load rating scenarios.
        ii. This value should be adjusted at the Engineer's discretion.

3. **TIRE CONTACT AREA**
   a. The tire contact area is calculated per AASHTO 3.27.3 and distributed through the fill depth above top of deck at 45° angle in each direction.
4. **TIRE CONTACT AREA OVERRIDE**
   a. A tire width and length for the both the rear and front axles is provided for unique cases where the geometry or condition of the deck may dictate using a different tire contact area than what AASHTO 3.27.3 specifies.
   b. These values should be input at the Engineer's discretion.
5. **Analysis**
   a. ***Deck Capacity (C_u)*** – Calculated as the F_y*S_x*(1-SL%) in units of k-in/in.
   b. ***Dead Load Moments***
      i. Displays the controlling moment formula based on the Simple/Cont. input.
         1. 0.125*w*L^2 for positive moment simple span analysis
         2. 0.08*w*L^2 for positive moment continuous span analysis
            a. 0.08 was selected based on available beam diagrams for continuous spans.
      ii. The calculated moment is shown for the following:
         1. ***Steel Open Grid Deck*** – Uses the *Total Weight (ksf)* input to calculate w.
         2. ***Fill*** – Equates to 0.000 k-in/in as fill cannot be input for open grid decks.
         3. ***Miscellaneous*** – Uses the *Misc. Dead Load (ksf)* input to calculate w.
   c. ***Live Load Moments***
      i. Displays the calculated positive moment for each rated truck. Both the rear and front axles are analyzed. Even though the front axle is typically much lighter, the smaller contact area will cause it to control in some cases.
      ii. Positive moments are calculated by determining if the tire contact area is wider than the stringer spacing.
         1. If tire width < stringer spacing
            a. Mu = R_1*(a+(R_1/2w))
            b. See *Figure 1: Simple Beam - Uniform Load Partially Distributed* in the Steel Corrugated Deck Section
         2. If tire width > stringer spacing
            a. Mu = 0.125*w*L^2 for positive moment simple span analysis
            b. Mu = 0.08*w*L^2 for positive moment continuous span analysis
               i. 0.08 was selected based on available beam diagrams for continuous spans.
      iii. Ratings are calculated based on Formula 6-1a (MCEB)
         1. RF = [C_u-(1.3*DL)]/(A*LL) (Eq. 8-1, MCEB Formula 6-1a)
      iv. Additional information on the analysis can be found to the right of the printed area.

General Notes:

- Per the engineer's discretion, reference Section 6.1.5.1-Decks in the Manual For Bridge Evaluation, 3rd Edition:

"Stringer-supported concrete deck slabs and metal decks that are carrying normal traffic satisfactorily need not be routinely evaluated for load capacity."



Looking North

16.4 x 0.7 = 11.41'
15.4 x 0.8 = 12.32'

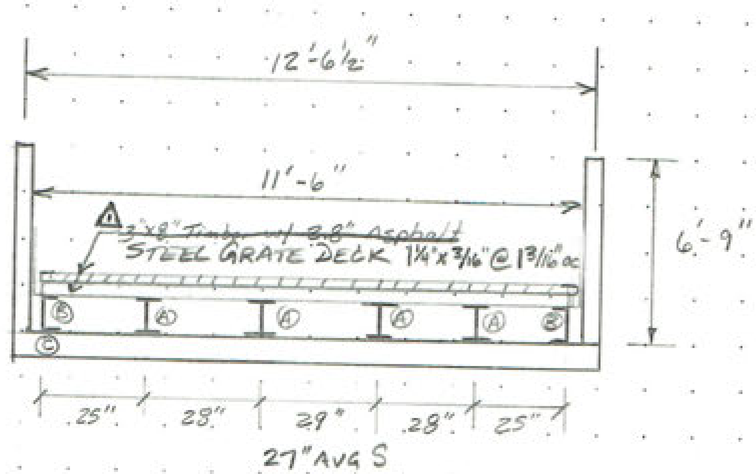
Δ Abutment

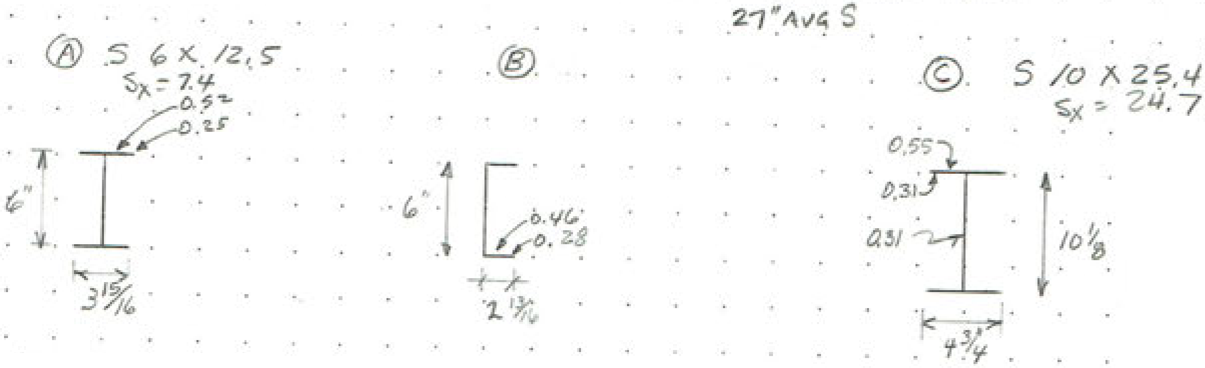
☐ Bent

○ Span

S Simple

C Continuous



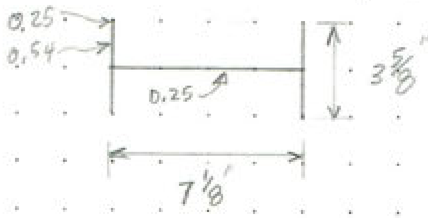


02-182-AA01-11-001

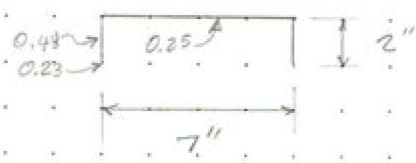
Inspection Date: 12-14-00 Page of

TOP CHORD & END POST

S 7 X 15.3 Area = 4.50
r = 0.77

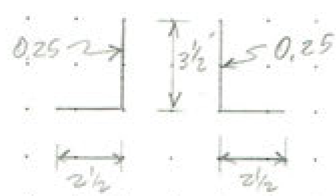


DIAGONALS & VERTICALS
C 7 X 9.8 (2 holes)
Area = 2.87
r = 0.58



△ Abutment
☐ Bent
○ Span
S Simple
C Continuous

Lower Chord @ MID SPAN
(2 holes)



A = 2.88

02-182-AA01-11-001

Inspection Date: 12-14-00 Page of

TBLRP-LFR Spreadsheet

Steel Deck

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Yoakum (13)	AADT ®:	50
County:	Lavaca (143)	# of Lanes:	1
Structure # :	AA01-75-001	Truck % (1% MIN):	1%
Location:	CR 280 Over Ponton Creek	EV Daily Crossing:	1 (1 or 10) One Direction
		Year Built:	2005
		Deck Descr:	5/4" x 3/16" Steel Open Grid Deck

Deck Inputs

DATA INPUT TABLE

Deck Type	Steel Open Grid Deck
Designation:	Nonstandard Grid
Fy (ksi):	50.0
*Main Beam (MB) Depth (in):	1.250
Main Beam (MB) thickness (in):	0.188
Main Beam (MB) Spacing (in):	1.188
MB Thickness Section Loss (%):	0%
Supplemental Bar Depth (in):	0.000
Supplemental Bar Thickness (in):	0.000
Supplemental Bars Btw Each MB:	0.0
Total Weight (ksf):	0.008
Original Sx (in^3/ft):	0.495
Misc. Dead Load (ksf):	0.000

*Get designated section properties from the table when applicable.

TIRE CONTACT AREA (in)**

Rear	AASHTO	Through Fill	Total
Width	20.000		20.000
HS Length	22.376		22.376
SHV Length	13.001		13.001
EV2 Length	12.4		12.4
EV3 Length	23.3		23.3
Front	**AASHTO**	**Through Fill**	**Total**
Width	10.000		10.000
HS/SHV Length	10.000		10.000
EV Length	10.0		10.0

DATA FOR LIVE LOAD DISTRIBUTION

Stringer Spacing (in):	28.000
Flange Width (in):	3.950
Calculated Deck Span Between Flange Tips (in):	24.050
Calculated Deck Span (in):	25.300
LL Impact Factor:	1.30

TIRE CONTACT AREA OVERRIDE (in)

	Width	Length
All Trucks Rear		
All Trucks Front		

**Tire contact areas referenced in AASHTO 3.27.3

Analysis

Deck Capacity (C_u)

$C_u = F_y * S_x * (1-SL\%)$

Cu = 50 * 0.495 * (1-0) = 2.061 k-in/in

Dead Load Moments Simple +Mmax = 0.125*w*l^2

Steel Open Grid Deck:	0.004 k-in/in
Fill:	0.000 k-in/in
Miscellaneous:	0.000 k-in/in
Total:	0.004 k-in/in

Live Load Moments

+Mmax = R1*(a+(R1/2w)) or = 0.080*w*l^2

M_{LL} HS:	2.735 k-in/in
M_{LL} H:	2.735 k-in/in
M_{LL} SHV_{SU4}:	3.045 k-in/in
M_{LL} SHV_{SU5}:	3.045 k-in/in
M_{LL} SHV_{SU6}:	3.045 k-in/in
M_{LL} SHV_{SU7}:	3.045 k-in/in
M_{LL} T3:	3.281 k-in/in
M_{LL} T3S2:	2.538 k-in/in
M_{LL} T3-3:	3.045 k-in/in
M_{LL} NRL:	3.045 k-in/in
M_{LL} EV_2:	3.505 k-in/in
M_{LL} EV_3:	3.505 k-in/in

Additional Notes

€ - Flexure Controls Rating
¥ - Based on H-20 Rating
£ - Flexure Controls Rating

€ HS Ratings		
HS Inventory:	HS 05.3	RF= 0.27
HS Operating:	HS 08.9	RF= 0.44
¥£ H RATING		
H Inventory:	H 05.3	RF= 0.27
H Operating:	H 08.9	RF= 0.44

AASHTO LEGAL LOADS RATING FACTORS

SU_4 Operating:	0.40	TYPE 3:	0.37
SU_5 Operating:	0.40	TYPE 3S2:	0.48
SU_6 Operating:	0.40	TYPE 3-3:	0.40
SU_7 Operating:	0.40	NRL:	0.40

EMERGENCY VEHICLE (EV) RATING FACTORS

EV_2 Operating:	0.35	EV_3 Operating:	0.35

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Open Grid Deck

Inputs

			Designation:	Nonstandard Grid	
			F_y:	50.0	ksi
Stringer Spacing:	28.000	in	Main Beam (MB) Depth:	1.250	in
Flange Width:	3.950	in	Main Beam (MB) thickness:	0.188	in
			Main Beam (MB) Spacing:	1.188	in
Calculated Deck Span Between Flange Tips = Stringer Spacing - Flange Width			MB Thickness Section Loss:	0	%
Calculated Deck Span Between Flange Tips:	24.050	in	Supplemental Bar Depth:	0.000	in
			Supplemental Bar Thickness:	0.000	in
Calculated Deck Span = Stringer Spacing - Flange Width + Deck Thickness			Supplemental Bars Btw Each MB:	0	
Calculated Deck Span:	25.300	in	Total Weight:	0.008	ksf
			Original Sx:	0.495	in^3/ft
LL Impact Factor:	1.30		Misc. Dead Load:	0.000	ksf
			Stringer Spacing:		in
			LL Impact Factor:	1.30	

Capacity

C_u = F_y*S*(1-SL%) =	50.0 ksi * 0.495 in^3/ft * (1 ft / 12 in) * (1 - 0)	=	2.061	k-in/in

Dead Load Moments

Dead load moments are calculated based on beam diagram tables for distributed loads for continuous spans. The following equation is used:

Continuous max (+)M 0.08*w*l^2

Steel Open Grid Deck M_{DL} =	0.08 * 0.008 ksf * (1 ft^2 / 144 in^2) * (28.000 in)^2	=	0.004	k-in/in
Fill M_{DL} =	No fill on open grid deck	=	0.000	k-in/in
Misc. Loads M_{DL} =	0.08 * (0.000 ksf) * (1 ft^2 / 144 in^2) * (28.000 in)^2	=	0.000	k-in/in
	Total	=	0.004	k-in/in

Live Load Moments

Assuming that the wheel width will be less than the girder spacing, moments will be calculated based on a simple beam with a uniform load partially distributed. (Mu = R1*(a+(R1/2w))). In cases where the loaded width is larger than the girder spacing, 0.125*w*l^2 will be used for simple span and 0.100*w*l^2 for continuous spans.

Rear Axle

HS Truck Axle		=	16	k
Wheel Distribution Width		=	20	in
Wheel Distribution Length =	1.250 * 16 k + 2 * 1.188 in	=	22.376	in
Distributed load to top of deck =	16 k / 20 in	=	0.800	k-in/in
Wheel Load (R1) =	16 k / 2	=	8	k
Distance from CL stringer to Edge of Tire Load Area (a) =	(25.300 in - 20 in) / 2	=	2.650	in
(+)M from beam diagrams =	(8 k * (2.650 in + 8 k / (2 * 0.800k-in/in))) / 22.376 in	=	2.735	k-in/in

Front Axle

HS Truck Axle		=	4	k
Wheel Distribution Width		=	10	in
Wheel Distribution Length =		=	10	in
Distributed load to top of deck =	4 k / 10 in	=	0.400	k-in/in
Wheel Load (R1) =	4 k / 2	=	2	k
Distance from CL stringer to Edge of Tire Load Area (a) =	(25.300 in - 10 in) / 2	=	7.650	in
(+)M from beam diagrams =	(2 k * (7.65 in + 2 k / (2 * 0.400 k-in/in))) / 10 in	=	2.030	k-in/in

Rating Factors

HS-20 INV RF =	(2.061 - (1.3 * 0.004))/(2.17 * 2.735 * 1.3)	=	0.27	
			HS 5.3	<<<
HS-20 OPR RF =	(2.061 - (1.3 * 0.004))/(1.3 * 2.735 * 1.3)	=	0.44	
			HS 8.9	<<<

Note: Values above are rounded (not all decimals shown).

Section 9: Timber Deck

1. **DATA INPUT TABLE**
    a. ***Deck Condition Rating*** – Input the condition rating for the timber deck per the most recent inspection performed.
    b. ***Deck Unit Weight (kcf)*** – Input the unit weight of the timber deck.
        i. This value is typically around 0.050 kcf for timber.
    c. ***Actual Plank Thickness (in)*** – Input the timber deck plank thickness.
        i. This thickness is used to calculate the capacity of the timber deck.
    d. ***Runners Thickness (in)*** – Input the runners' thickness atop the deck.
        i. Do not include as runners if members are not within wheel path(s).
        ii. This value will be used to calculate dead loads.
        iii. A thickness value greater than 0" will also impact the Width of Deck Resist. Wheel Load.
        iv. Leave cell blank or enter 0" if no surfacing is present.
    e. ***Runners Unit Weight (kcf)*** – Input the unit weight of the runners.
        i. This value is typically around 0.050 kcf for timber.
        ii. This value is typically around 0.490 kcf for steel.
        iii. Leave cell blank or enter 0" if no surfacing is present.
    f. ***Asphalt Wearing Surface Thickness (in)*** – Thickness value greater than 0 impacts the Width of Deck Resist. Wheel Load.
        i. Leave cell blank or enter 0" if no surfacing is present.
    g. ***Asphalt Wearing Surface Unit Weight (kcf)*** – Input the unit weight of the asphalt surfacing.
        i. This value is typically around 0.145 kcf for asphalt.
    h. ***Fill Material Depth (in)*** – Input the depth of fill atop the deck.
    i. ***Fill Material Unit Weight (kcf)*** – Input the unit weight of the fill material.
    j. ***Misc. Dead Load (ksf)*** – Input any additional weight (in kips per square feet) acting on the deck that will be used for dead load calculations.
    k. ***Stringer Spacing (in)*** – Input the spacing between stringers.
        i. Value should be centerline to centerline.
        ii. This value is used to calculate the controlling deck span.
    l. ***Stringer Top Flange Width (in)*** – Input width of the top flange of the superstructure members.
        i. The Controlling Deck Span will be reduced per the Top Flange Width.

    NOTE: While dead load values typically do not impact most timber decks due to smaller stringer spacings, the values in this tab can be referenced in other tabs and may impact other members greatly.

Width of Deck Resisting Wheel Load Check	
No Surfacing (in): *	= 1 plank width
Surfacing Present (in): **	= 2 planks widths
Laminated Deck (in): *	= 15 inches + deck thickness

*AASHTO 2002 17th Edition - 3.25.1.1
**From original TBLRP

Figure 2: Width of Deck Resisting Load Check

2. **DECK PROPERTIES**
   a. ***Is Deck Laminated*** – Select "Yes" or "No" from the drop-down list.
      i. This cell impacts the calculations performed within the Width of Deck Resisting Wheel Load (in) section. See explanations below for additional information.
   b. ***Width of Deck Resisting Wheel Load (in)*** – This cell will calculate the portion of the deck the user is able to consider for the deck's section modulus, and ultimately the deck's allowable moment. The three scenarios used for this calculation are as follows:

Width of Deck Resisting Wheel Load Scenarios	
No Surfacing:	1 plank width, with a minimum of 10". (AASHTO 2002 17th Edition - 3.25.1.1)
Surfacing Present:	2 plank widths. (Assuming surfacing can transfer loads)
Laminated Decking:	15" plus deck thickness for laminated decks. (AASHTO 2002 17th Edition - 3.25.1.1)

Figure 3: Width of Deck Resisting Wheel Load

   c. ***S_X (in^3)*** – This cell will calculate the section modulus based upon previous user inputs. The timber deck's section modulus is calculated as follows:

$$S_X = (1/6) * \text{Width of Deck Resisting Wheel Load} * (\text{Plank Thickness})^2 \qquad \text{(Eq. 9-1)}$$

d. ***The Allowable Bending Stress, F_b (ksi)*** – Input a value for the allowable bending stress based upon the most recent bridge inspection performed.

   i. A recommended value for southern pine, based upon the deck condition rating, is provided directly to the right of the printed section.

DECK PROPERTIES		
Is Deck Laminated:		
Width of Deck Resist. Wheel Load (in):	10.000	
S_x (in^3):	0.000	
Allowable Bending Stress, F_b (ksi):		<Recommend using: 1 For Allowable Bending Stress
M_{ALL} (k-in):	0.0	

Figure 4: Allowable Bending Stress Guidance

   ii. A reference table for the user is located to the right of the printed section within TBLRP-LFR.

Timber Condition	Allowable Bending Stress
Good (Minor weathering and decay)	2.0 KSI
Fair (Substantial decay or damage)	1.5 KSI
Poor (Severe deterioration)	1.0 KSI

The Allowable bending stress recommendations are based upon seasoned and pressure treated southern pine. These values include a 33% increase for flatwise use and short duration loading.

Figure 5: Allowable Bending Stress values for Southern Pine (Deck)

e. ***M_{ALL} (k-in)*** – This cell will calculate the allowable moment based upon previous user inputs. The timber deck's allowable moment is calculated as follows:

$$M_{ALL} = S_X * F_b \quad \text{(Eq. 9-2)}$$

3. **CONTROLLING DECK SPAN CHECK**

a. ***Deck Span$_1$ (in)*** – This cell will calculate the first Deck Span check based upon previous user inputs.

   i. This value cannot exceed the value calculated in the second Deck Span check.

b. ***Deck Span$_2$ (in)*** – This cell will calculate the second Deck Span check based upon previous user inputs.

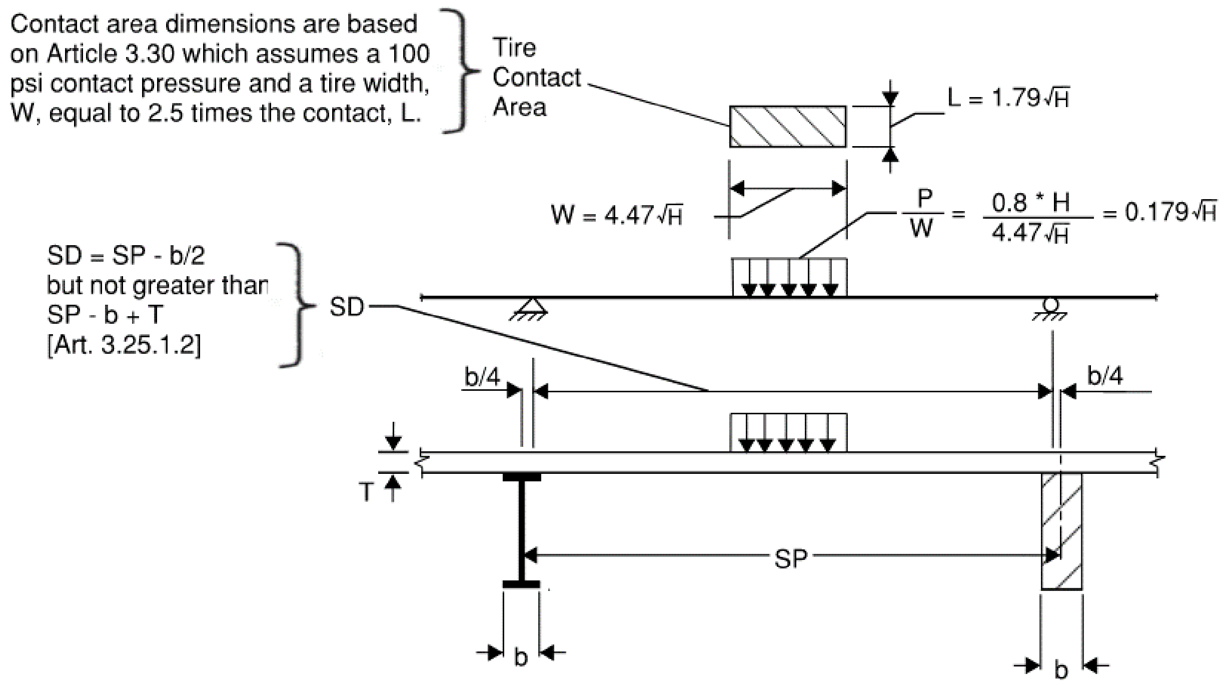
c. ***Controlling Deck Span (in)*** – This cell takes the minimum value the two Deck Span scenario calculations above. The controlling Deck span formula checks are as follows:

$$\text{Deck Span}_1 = \text{Stringer Spacing} - (\text{Top Flange Width}/2) \le \text{Deck Span}_2 \quad \text{(Eq. 9-3)}$$
$$\text{Deck Span}_2 = \text{Stringer Spacing} - \text{Top Flange Width} + \text{Plank Depth} \quad \text{(Eq. 9-4)}$$

d. ***Tire Width (in)*** – This cell calculates the Tire Width based upon previous user inputs. The width of a tire acting upon the deck can be calculated as follows:

$$\text{Tire Width} = 4.47 * \sqrt{Truck\ H - Rating} \quad \text{(Eq. 9-5)}$$

Additional details for these calculations can be found on the following page.



If SD > W
$$M_{LL} = \frac{8}{10} * \frac{P}{2} * \left(\frac{SD}{2} - \frac{W}{4} \right) = \frac{8}{10} * 0.4 * H * \left(\frac{SD}{2} - \frac{4.74 * \sqrt{H}}{4} \right)$$
$$M_{LL} = 0.16 * H * SD - 0.358 * H^{1.5} \qquad \text{(Eq. 9-6)}$$

If SD ≤ W
$$M_{LL} = \frac{8}{10} * \frac{P}{W} * \frac{SD^2}{8} = \frac{8}{10} * 0.179 * \sqrt{H} * \frac{SD^2}{8}$$
$$M_{LL} = 0.0179 * \sqrt{H} * SD^2 \qquad \text{(Eq. 9-7)}$$

Where

Where	M_{LL} = Live Load Moment	(IN-KIPS)
	SD = Effective Deck Span [See above]	(IN)
	W = Width of Tire = 4.47 $\sqrt[4]{H}$ [See above]	(IN)
	H = Gross Weight of H-truck Live Load	(TONS)
	P = Weight of rear wheel = 0.8 * H	(KIPS)
	$\frac{8}{10}$ = Continuity factor [See Article 3.25.4]	

Figure 6: Timber Deck Live Load

4. **Analysis**

   a. Based upon the inputs in previous sections, a few different scenarios could arise for timber decks. If the Controlling Deck Span is greater than the calculated tire width, then Eq. 9-6 will be used. When iteration is required for Eq. 9-6 (made evident by the cells being illuminated with a yellow fill), please select the highlighted Iteration buttons in the bottom left of this section.

      i. Refer to the explanation below and see *Figure 6: Timber Deck Live Load* and *Figure 7: Timber Deck Iteration Required Example* for further explanation on iteration within the Timber Module.

<u>Solving by Iteration (using Equation 9-6):</u>

$W_{G\text{-}H}$ = Gross Weight of H-Truck Live Load = H-Rating

Note: $3120 = 1 / (0.0179)^2$

$M_{ALL} = F_b * (1/6) * (\text{Width of Deck Resisting Wheel Load}) * (\text{Deck Thickness})^2$

$M_{DL} = (1/8) * (\text{Total Dead Load}) * (\text{Stringer Spacing})^2$

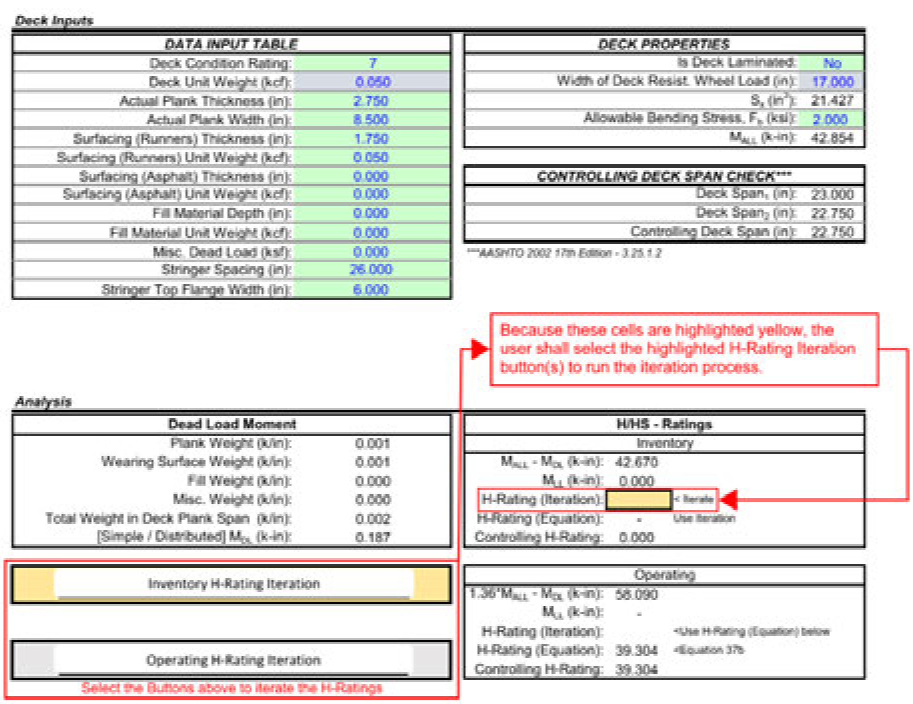
If Controlling Deck Span > Tire Width

$M_{LL} = 0.160 * (W_{G\text{-}H}) * (SD) - 0.358 * (W_{G\text{-}H})^{1.5}$

>>> Substitute $(M_{ALL} - M_{DL})$ for M_{LL} <<<

$(M_{ALL} - M_{DL}) = 0.160 * (W_{G\text{-}H}) * (SD) - 0.358 * (W_{G\text{-}H})^{1.5}$

>>> Solve The Above Equation by Iteration <<<



Deck Inputs

DATA INPUT TABLE	
Deck Condition Rating:	7
Deck Unit Weight (kcf):	0.050
Actual Plank Thickness (in):	2.750
Actual Plank Width (in):	8.500
Surfacing (Runners) Thickness (in):	1.750
Surfacing (Runners) Unit Weight (kcf):	0.050
Surfacing (Asphalt) Thickness (in):	0.000
Surfacing (Asphalt) Unit Weight (kcf):	0.000
Fill Material Depth (in):	0.000
Fill Material Unit Weight (kcf):	0.000
Misc. Dead Load (ksf):	0.000
Stringer Spacing (in):	26.000
Stringer Top Flange Width (in):	6.000

DECK PROPERTIES	
Is Deck Laminated:	No
Width of Deck Resist. Wheel Load (in):	17.000
S_x (in^3):	21.427
Allowable Bending Stress, F_b (ksi):	2.000
M_{ALL} (k-in):	42.854

CONTROLLING DECK SPAN CHECK***	
Deck $Span_1$ (in):	23.000
Deck $Span_2$ (in):	22.750
Controlling Deck Span (in):	22.750

***AASHTO 2002 17th Edition - 3.25.1.2

Because these cells are highlighted yellow, the user shall select the highlighted H-Rating Iteration button(s) to run the iteration process.

Analysis

Dead Load Moment	
Plank Weight (k/in):	0.001
Wearing Surface Weight (k/in):	0.001
Fill Weight (k/in):	0.000
Misc. Weight (k/in):	0.000
Total Weight in Deck Plank Span (k/in):	0.002
[Simple / Distributed] M_{DL} (k-in):	0.187

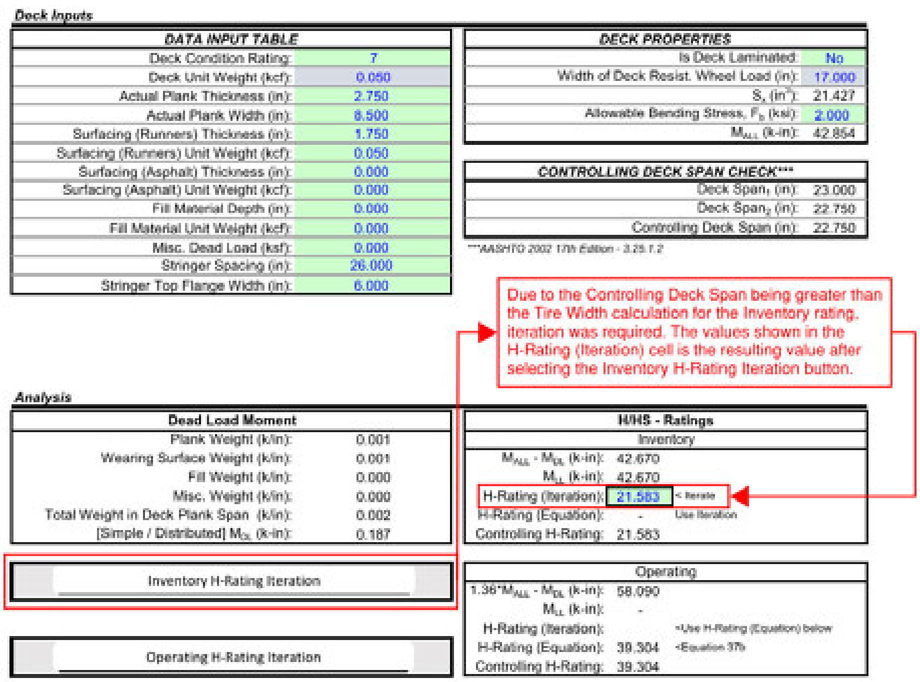
Inventory H-Rating Iteration

Operating H-Rating Iteration

Select the Buttons above to iterate the H-Ratings

H/HS - Ratings		
Inventory		
M_{ALL} - M_{DL} (k-in):	42.670	
M_{LL} (k-in):	0.000	
H-Rating (Iteration):		< Iterate
H-Rating (Equation):	-	Use Iteration
Controlling H-Rating:	0.000	
Operating		
1.36*M_{ALL} - M_{DL} (k-in):	58.090	
M_{LL} (k-in):	-	
H-Rating (Iteration):		<Use H-Rating (Equation) below
H-Rating (Equation):	39.304	<Equation 37b
Controlling H-Rating:	39.304	

Figure 7: Timber Deck Iteration Required Example



Deck Inputs

DATA INPUT TABLE	
Deck Condition Rating:	7
Deck Unit Weight (kcf):	0.050
Actual Plank Thickness (in):	2.750
Actual Plank Width (in):	8.500
Surfacing (Runners) Thickness (in):	1.750
Surfacing (Runners) Unit Weight (kcf):	0.050
Surfacing (Asphalt) Thickness (in):	0.000
Surfacing (Asphalt) Unit Weight (kcf):	0.000
Fill Material Depth (in):	0.000
Fill Material Unit Weight (kcf):	0.000
Misc. Dead Load (ksf):	0.000
Stringer Spacing (in):	26.000
Stringer Top Flange Width (in):	6.000

DECK PROPERTIES	
Is Deck Laminated:	No
Width of Deck Resist. Wheel Load (in):	17.000
S_x (in^3):	21.427
Allowable Bending Stress, F_b (ksi):	2.000
M_{ALL} (k-in):	42.854

CONTROLLING DECK SPAN CHECK***	
Deck Span$_1$ (in):	23.000
Deck Span$_2$ (in):	22.750
Controlling Deck Span (in):	22.750

***AASHTO 2002 17th Edition - 3.25.1.2

Due to the Controlling Deck Span being greater than the Tire Width calculation for the Inventory rating, iteration was required. The values shown in the H-Rating (Iteration) cell is the resulting value after selecting the Inventory H-Rating Iteration button.

Analysis

Dead Load Moment	
Plank Weight (k/in):	0.001
Wearing Surface Weight (k/in):	0.001
Fill Weight (k/in):	0.000
Misc. Weight (k/in):	0.000
Total Weight in Deck Plank Span (k/in):	0.002
[Simple / Distributed] M_{DL} (k-in):	0.187

Inventory H-Rating Iteration

Operating H-Rating Iteration

H/HS - Ratings		
Inventory		
M_{ALL} - M_{DL} (k-in):	42.670	
M_{LL} (k-in):	42.670	
H-Rating (Iteration):	21.583	< Iterate
H-Rating (Equation):	-	Use Iteration
Controlling H-Rating:	21.583	
Operating		
1.36*M_{ALL} - M_{DL} (k-in):	58.090	
M_{LL} (k-in):	-	
H-Rating (Iteration):		<Use H-Rating (Equation) below
H-Rating (Equation):	39.304	<Equation 37b
Controlling H-Rating:	39.304	

Figure 8: Timber Deck Iteration Utilized Example

b. If the Controlling Deck Span is less than or equal to the calculated tire width, then Eq. 9-7 will be used:

<u>Solving using Equation 9-7:</u>

W_{G-H} = Gross Weight of H-Truck Live Load = H-Rating

If Controlling Deck Span ≤ Tire Width

$M_{LL} = 0.0179 * (W_{G-H})^{0.5} * (SD)^2$

>>> Substitute ($M_{ALL} - M_{DL}$) for M_{LL} <<<

$(M_{ALL} - M_{DL}) = 0.0179 * (W_{G-H})^{0.5} * (SD)^2$

>>> Rearrange Equation and Solve <<<

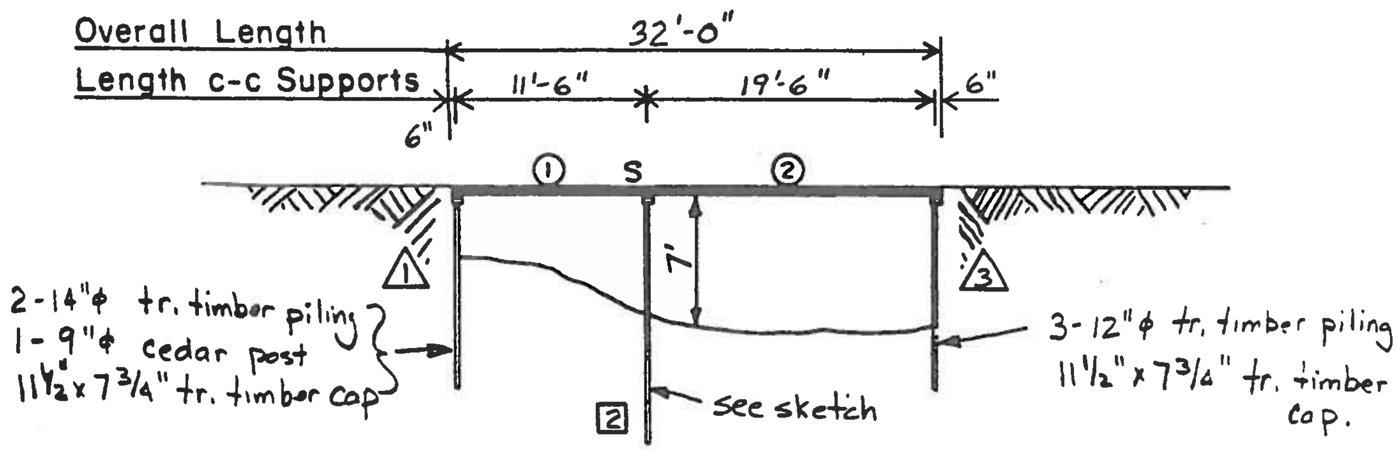
(W_{G-H}) = H-Rating = $3120 * (M_{ALL} - M_{DL})^2 / (SD)^4$

TEXAS BRIDGE LOAD RATING PROGRAM

RATING EXAMPLE

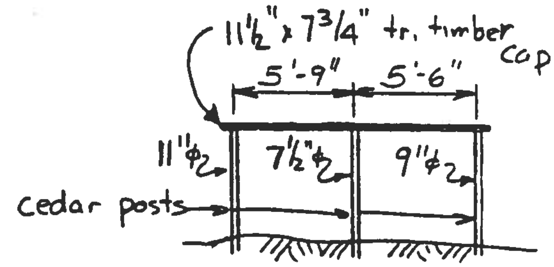
CEDAR CREEK BRIDGE (Date Built: 1934)

Bastrop County	Posted Load Restriction: 8 TONS
I.D. No. AA0082-001	Deck: Treated Southern Pine 2.75" x 8.5" Planks with 1.75" Timber Runners Good Condition
1-Lane Roadway	

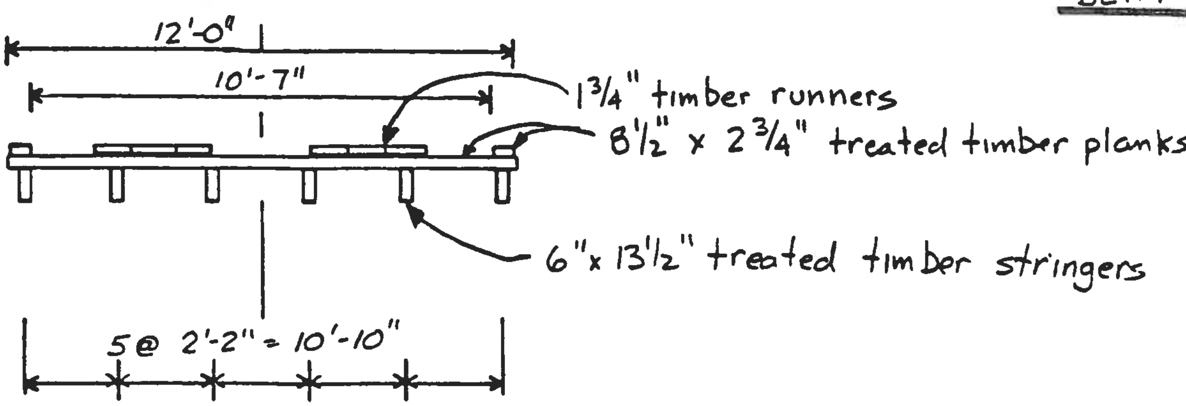


LEGEND
- ○ Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support

SIDE VIEW
(Looking South)



BENT 2



SPANS 1 & 2

TBLRP-LFR Spreadsheet

Timber Deck (ASD)

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Austin (14)	AADT ®:	50	# of Lanes:	1
County:	Bastrop (011)	Truck % (1% MIN):	1%		
Structure # :	AA00-82-001	EV Daily Crossing:	1	(1 or 10)	One Direction
Location:	Roadway Over Cedar Creek	Year Built:	1934		
		Deck Descr:	2.75" Timb. Deck w/ 1.75" Timb. Runners		

Deck Inputs

DATA INPUT TABLE	
Deck Condition Rating:	7
Deck Unit Weight (kcf):	0.050
Actual Plank Thickness (in):	2.750
Actual Plank Width (in):	8.500
Surfacing (Runners) Thickness (in):	1.750
Surfacing (Runners) Unit Weight (kcf):	0.050
Surfacing (Asphalt) Thickness (in):	0.000
Surfacing (Asphalt) Unit Weight (kcf):	0.000
Fill Material Depth (in):	0.000
Fill Material Unit Weight (kcf):	0.000
Misc. Dead Load (ksf):	0.000
Stringer Spacing (in):	26.000
Stringer Top Flange Width (in):	6.000

DECK PROPERTIES	
Is Deck Laminated:	No
Width of Deck Resist. Wheel Load (in):	17.000
S_x (in^3):	21.427
Allowable Bending Stress, F_b (ksi):	2.000
M_{ALL} (k-in):	42.854

CONTROLLING DECK SPAN CHECK***	
Deck $Span_1$ (in):	23.000
Deck $Span_2$ (in):	22.750
Controlling Deck Span (in):	22.750

****AASHTO 2002 17th Edition - 3.25.1.2*

Analysis

Dead Load Moment	
Plank Weight (k/in):	0.001
Wearing Surface Weight (k/in):	0.001
Fill Weight (k/in):	0.000
Misc. Weight (k/in):	0.000
Total Weight in Deck Plank Span (k/in):	0.002
[Simple / Distributed] M_{DL} (k-in):	0.187

Inventory H-Rating Iteration

Operating H-Rating Iteration

H/HS - Ratings		
Inventory		
M_{ALL} - M_{DL} (k-in):	42.670	
M_{LL} (k-in):	42.670	
H-Rating (Iteration):	21.583	< Iterate
H-Rating (Equation):	-	Use Iteration
Controlling H-Rating:	21.583	
Operating		
1.36*M_{ALL} - M_{DL} (k-in):	58.090	
M_{LL} (k-in):	-	
H-Rating (Iteration):		<Use H-Rating (Equation) below
H-Rating (Equation):	39.304	<Equation 37b
Controlling H-Rating:	39.304	

Additional Notes

Bridge condition and traffic values assumed.
Roadway unknown.

€ - Flexure Controls Rating
¥ - Based on H-20 Rating
£ - Flexure Controls Rating

€ HS Ratings		
HS Inventory:	HS 21.6	RF= 1.08
HS Operating:	HS 39.3	RF= 1.97
¥£ H RATING		
H Inventory:	H 21.6	RF= 1.08
H Operating:	H 39.3	RF= 1.97

AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	1.97	TYPE 3:	1.97
SU_5 Operating:	1.97	TYPE 3S2:	1.97
SU_6 Operating:	1.97	TYPE 3-3:	1.97
SU_7 Operating:	1.97	NRL:	1.97
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.88	EV_3 Operating:	1.97

Values calculated based on Allowable Stress Method

Timber Deck

Inputs

Surfacing (Runners) Thickness:	1.750 in	Timber Deck (Item 58) Condition Rating:	7
Surfacing (Runners) Unit Weight:	0.050 kcf	F_b:	2.000 ksi
Surfacing (Asphalt) Thickness:	0.000 in	Timber Deck Unit Weight:	0.050 kcf
Surfacing (Asphalt) Unit Weight:	0.000 kcf	Deck Thickness:	2.750 in
Fill Material Depth:	0.000 in	Actual Plank Width:	8.500 in
Fill Material Unit Weight:	0.000 kcf	Stringer Spacing:	26.000 in
Misc. Dead Load:	0.000 ksf	Stringer Top Flange Width:	6.000 in
		Is Deck Laminated:	No

Dead Loads

Deck (k/in) =	[(2.750 in * 17.000 in) * (1 ft^2 / 144 in^2)] * 0.050 kcf * (1 ft / 12 in)	=	0.001 k/in
Wearing Surface (k/in) =	(1.750 in * 0.050 kcf) * (1 ft^2 / 144 in^2)] * 17.000 in * (1 ft / 12 in)	=	0.001 k/in
Total Dead Load (k/ft) =			0.002 k/in

Moment Analysis

Width of Deck Resisting Wheel Load (in) =	2 * Plank Width (Surfacing Present Scenario) = 2 * 8.5 in	=	17.000 in
S_x (in^3) =	(1/6) * Width of Deck Resisting Wheel Load * Plank Depth * Plank Depth		
S_x (in^3) =	(1/6) * 17.000 in * 2.750 in * 2.750 in	=	21.427 in^3
Deck Span, SD =	Stringer Spacing - (Stringer Top Flange Width / 2) = 26.000 in - (6.000 in /2)	=	23.000 in
	NOTE: The Deck Span cannot be greater than the following:		
Deck Span, SD =	Stringer Spacing - Stringer Top Flange Width + Deck Plank Thick.		
Deck Span, SD =	26.000 in - 6.000 in + 2.750 in	=	22.750
Controlling Deck Span, SD =			22.750 in
M_{ALL} =	F_b * S_x = 2.000 ksi * 21.427 in^3	=	42.9 k-in
M_{DL} =	(1/8) * Total Dead Load (k/in) * Stringer Spacing $(in)^2$		
M_{DL} =	(1/8) * 0.002 k/in * 26.000 in * 26.000 in	=	0.187 k-in

H and HS Inventory Analysis

M_{ALL} - M_{DL} =	(42.9 k-in) - (0.187 k-in)	=	42.670 k-in
Tire Width, W =	4.47 * (M_{ALL} - M_{DL}) / (0.0179 * Controlling Deck $Span^2$)		
Tire Width, W =	4.47 * 42.670 k-in / (0.0179 * 22.750 in * 22.750 in)	=	20.59 in
	22.750 in > 20.59 in		
	So, SD > W, Use Equation 37a and solve for the H-Rating by iteration		
{equation 37a} M_{LL} =	0.16 * (H-Rating) * (Controlling Deck Span) - 0.358 * $(\text{H-Rating})^{1.5}$		
	>>>Substitute (M_{ALL} - M_{DL}) for M_{LL}<<<		
(M_{ALL} - M_{DL}) =	0.16 * (H-Rating) * (Controlling Deck Span) - 0.358 * $(\text{H-Rating})^{1.5}$		
	42.670 k-in = 0.16 * (H-Rating) * (22.750 in) - 0.358 * $(\text{H-Rating})^{1.5}$	=	Iterate
Inventory H-Rating =			**H 21.6** <<<
Inventory HS-Rating =			**HS 21.6** <<<

H and HS Operating Analysis

1.36 * M_{ALL} - M_{DL} =	(1.36 * 42.9 k-in) - (0.187 k-in)	=	58.090 k-in
Tire Width, W =	4.47 * (1.36 * M_{ALL} - M_{DL}) / (0.0179 * Controlling Deck $Span^2$)		
Tire Width, W =	4.47 * 58.090 k-in / (0.0179 * 22.750 in * 22.750 in)	=	28.03 in
	22.750 in ≤ 28.03 in		
	So, SD ≤ W, Use Equation 37b and solve for the H-Rating		
{equation 37b} M_{LL} =	0.0179 * (H-Rating)(1/2) * (Controlling Deck $Span^2$)		
{rearranged equation 37a} OPR H-Rating =	3120 * (1.36 * M_{ALL} - M_{DL})^2 / (Controlling Deck Span)^4		
OPR H-Rating =	3120 * (58.090 k-in)^2 / $(22.750)^4$	=	**H 39.3** <<<
OPR HS-Rating =	3120 * (58.090 k-in)^2 / $(22.750)^4$	=	**HS 39.3** <<<

Note: Values above are rounded (not all decimals shown).

Section 10: Steel Stringer (Simple)

1. **DATA INPUT TABLE**
    a. ***Span ID*** - The Span ID should correspond with the span numbers used on the bridge plans or inventory record.
    b. ***Span Length (ft)*** – Input the length of the span.
    c. ***Span Bearing Length Deduct (ft)*** – This is the portion of the overall span located at each end of the span that is between the centerline of the bearing and the centerline of the bent. The value to be entered is the sum of these two described end portions of the span, measured along the centerline of the roadway. The spreadsheet subtracts this value from the Span Length to calculate the effective flexural length of the steel stringer.

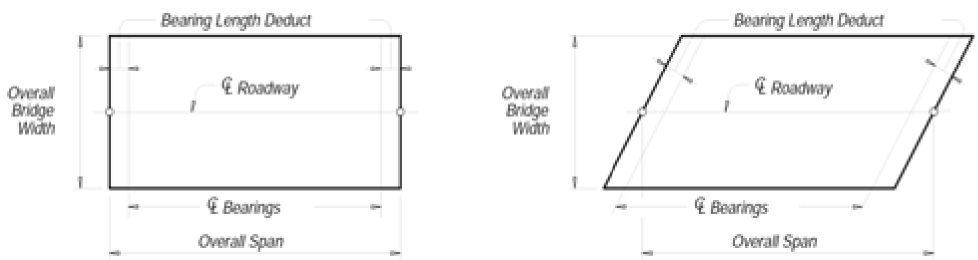


Figure 9: Bearing Length Deduct

    d. ***F_y (ksi)*** – Input the yield stress of the steel stringer. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.
    e. ***Stringer Spacing (ft)*** – Input the stringer spacing from centerline to centerline.
    f. ***Misc. Comp Dead Load per Beam (k/ft)*** – Input the miscellaneous composite dead load per beam. These are loads that were applied after a composite deck is in place. This includes any railing, sidewalks, median, and curbs placed on the composite section.
        i. Do not input miscellaneous composite dead loads if the deck is non-composite.
        ii. If the user inputs a Misc. Comp Dead Load when the deck is non-composite, the dead load value will be considered as a Non-Comp Dead Load along the beam.
    g. ***Misc. Non-Comp Dead Load per Beam (k/ft)*** – Input the miscellaneous non-composite dead load per beam. These are for permanent loads beyond the self-weight applied to the beam before the slab is cast. This should include the weight of diaphragms, if any. Calculate this load per ft per beam by taking the total non-composite dead load for the entire span, in kips, and dividing it by the total length of all stringers on the entire span.
    h. ***Top Cover Plate Width (in)*** – Input the top cover plate width if present at midspan.
    i. ***Top Cover Plate Thickness (in)*** – Input the top cover plate thickness if present at midspan.
    j. ***Bottom Cover Plate Width (in)*** - Input the bottom cover plate width if present at midspan.
    k. ***Bottom Cover Plate Thickness (in)*** – Input the bottom cover plate thickness if present at midspan.
    l. ***Bottom Flange Unbraced Length, Lb-b (ft)*** – Input the unbraced length for the bottom flange.

m. ***Top Flange Unbraced Length, Lb-t (ft)*** – Input the unbraced length for the top flange.
   i. This module considers the top flange fully braced when in contact with a concrete deck, steel corrugated deck, and a steel plate deck. When one of these deck types are selected in the Deck Inputs below, the program will default the top flange unbraced length to equal 0’ in its analysis in column AJ.
   ii. Research has shown that the beam does not have to be embedded in the deck nor does the deck have to be concrete to provide effective lateral bracing. The following cases will provide effective lateral bracing. The first three cases may be analyzed as fully braced. In the last two cases, the beam should be analyzed with an unbraced length equal to half the span length. In the last case, if the depth of base is substantially greater than 6 inches the beam may be analyzed as fully braced.
      1. Concrete deck cast on top of the compression flange.
      2. Corrugated metal deck. The deck sections should be interconnected adequately to ensure that the deck acts as a unit.
      3. Laminated timber deck.
      4. Timber plank deck with timber runners. Each of the two runners should be about 2 feet wide and the individual runner planks should be securely attached to the deck.
      5. Timber plank deck covered with at least 6 inches of base and asphaltic overlay.
   iii. In all of the above cases, the deck should be in contact with the flange. The deck should be secured to the superstructure at sufficient points to ensure that the entire deck does not shift laterally. Timber plank decks should be evaluated conservatively when used on bending members deeper than about 24 inches.

2. **DECK INPUTS**
   a. ***Import Values from Defined Deck Module*** – Select a deck module from the drop-down list to import previously input deck dead load info.
      i. The deck modules that aren’t in use will not be displayed in the drop-down list.
      ii. Select ‘No Deck Import’ to define a new deck and dead loads.
      iii. Deck modules that are not completely filled out may not import the desired loads.
   b. ***Deck Type*** – Select the Deck Type to use for the analysis.
      i. This is automatically filled in when values are imported. The cell is available to edit if ‘No Deck Import’ is selected.
      ii. Deck Type Options:
         1. ‘Concrete Deck’
         2. ‘Steel Corrugated Deck’
         3. ‘Steel Plate Deck’
         4. ‘Steel Open Grid Deck’
         5. ‘Timber Deck’
   c. ***Deck Designation [Steel Corrugated Deck, Steel Open Grid Deck only]*** – Select the deck designation from the drop down. This will calculate the Deck Weight field.

        i. If the desired deck designation is not in the drop-down, type in the designation name and the Deck Weight input will have to be manually calculated.

   d. ***Deck Thickness (in) [Concrete Deck, Steel Plate Deck, Timber Deck only]*** – Input the deck thickness.
        i. ***Deck Weight (ksf)*** below will automatically calculate based upon the standard material unit weights of the selected deck type.
   e. ***Composite Action (Y/N) [Concrete Deck Only]*** – Select 'Y' if shear studs are present in the manner that creates composite action with the deck, otherwise select 'N'.
   f. ***f'c (ksi) [Concrete Deck Only]*** – Enter the compressive strength of the concrete deck. This value is recommended based upon the date built, as seen in *Appendix A*.
   g. ***Slab Embedment (in) [Concrete Deck Only]*** – Some steel bridge structures have been built with the top flange of the stringer embedded in the slab. The measurement is from the bottom of the slab to the top of the flange. If the plans show a haunch over the top of the beam at midspan, the depth may be entered as a negative embedment.
   h. ***Deck Weight (ksf)*** – Value imported from deck module or calculated based on deck thickness input.
        i. This cell can be overwritten at the Engineer's discretion.
   i. ***Fill Weight (ksf)*** – Input the weight of fill acting on the deck.
   j. ***Wearing Surface Weight (ksf)*** – Input the weight of wearing surface acting on the deck.
   k. ***Misc. Loads (ksf)*** – Input any additional deck dead loads to be included.

3. **STRINGER PROPERTIES**
   a. ***Standard Beam Designation*** – Select a beam designation from the dropdown list.
        i. The dropdown list has been compiled from the AISC publication Iron and Steel Beams 1873 to 1972, otherwise known as *Historical Record, Dimensions and Properties, Rolled Shapes, Steel and Wrought Iron Beams & Columns, As Rolled in U.S.A., Period 1873 to 1972, With Sources as Noted,* compiled and edited by Herbert W. Ferris. The dropdown list also consists of the HP, S, and W-Shapes as provided by the AISC Shapes Database (V16.0).
        ii. The selected designation will populate the section dimensions below.
            1. Each section dimension can be overwritten to be the "remaining section" if section loss is present at the Engineer's discretion.
        iii. A new stringer designation can be created by inputting all of the section dimensions.
            1. ***Rolled Section Depth (in)*** – Input the rolled section depth of the stringer.
            2. ***Web Thickness (in)*** – Input the stringer web thickness.
            3. ***Flange Width (in) –*** Input the stringer flange width.
            4. ***Top Flange Thickness (in) –*** Input the stringer top flange thickness.
            5. ***Bottom Flange Thickness (in) –*** Input the stringer bottom flange thickness.
            6. ***Fillet Radius (in) –*** Input the stringer fillet radius.
            7. ***Compact Override (Y/N) –*** Input 'Y' to analyze the member as compact when the provided geometry states otherwise.

a. If this option is selected, please document in the Additional Notes the justification for analyzing the member as compact.
b. If the member is compact given the provided geometry, this input will be locked from editing.

8. ***Section Modulus, S (in^3)*** – Calculated from the section dimensions and cannot be manually input.

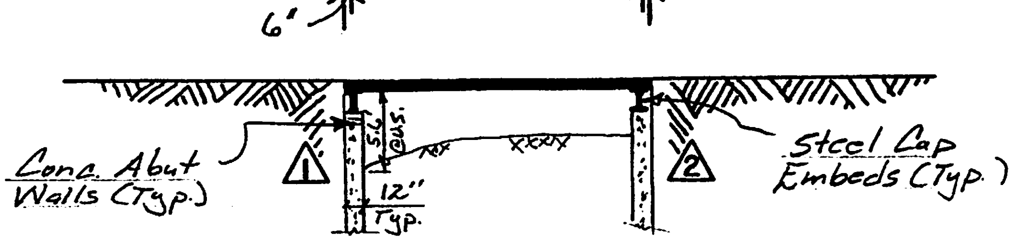
iv. For typical member shapes used for analysis, see *Appendix A.*

4. **LIVE LOAD FACTORS**
   a. ***Deck Type for LLDF*** – Select the deck type to calculate the corresponding live load distribution factors (LLDF). In most cases it will match the deck type used for Deck Inputs.
      i. For Steel Open Grid Decks and Nail/Glue Laminated Timber decks, the deck thickness is needed for the LLDF.
   b. ***Stringer Location*** – Select interior or exterior stringer.
      i. For exterior stringers, the LLDF must be calculated by the user and input in the Override column.
   c. ***LLDF Table*** – This table shows the calculated LLDFs (*AASHTO Table 3.23.1*) and the Impact Factor (IM) calculated as 1 + (50 / (Length + 125)) < 1.3. An override column is provided for use at the Engineer's discretion.
5. **Analysis**
   a. ***Stringer Capacity***
      i. See the flowchart in *Appendix C* for determining controlling moment capacities of non-hybrid, unstiffened, steel I-beams and plate girders according to the provisions of *AASHTO 10.48* through *10.50*.
         1. Per *AASHTO 10.48.3*, a transition (straight line interpolation) is allowed between *Eq. 10-92* and *Eq. 10-98* as long as the web thickness always satisfies *Eq. 10-94*.
   b. ***Dead Load Moments (M_{DL})***
      i. M_{DL} – All dead load moments are calculated as (1/8) * w_{DL} * L^2
      ii. M_{deck} – Includes Deck Weight and Misc. Loads inputs.
      iii. M_{beam} – Self weight of steel stringer and all cover plates calculated by the total cross-sectional area multiplied by 0.49 k/ft^3.
      iv. $M_{misc\ comp\ DL}$ – Includes Misc. Comp Dead Load per Beam input.
      v. $M_{misc\ non\text{-}comp\ DL}$ – Includes Misc. Non-Comp Dead Load per Beam input.
      vi. $M_{fill/wearing\ surface}$ – Includes Fill Weight and Wearing Surface Weight inputs.
   c. ***Live Load Moments (M_{LL})***
      i. Distributed Live Load plus Impact moments per truck based on values from worksheets *LIVE LOADS*.
   d. Additional information on the analysis performed can be found to the right of the printed section.

District 16 County 013 Cont.-Sec. AA01-91 Structure 001 Route Central Ln.

Overall Length 30'-0"

Length c-c Supports 29'-0"



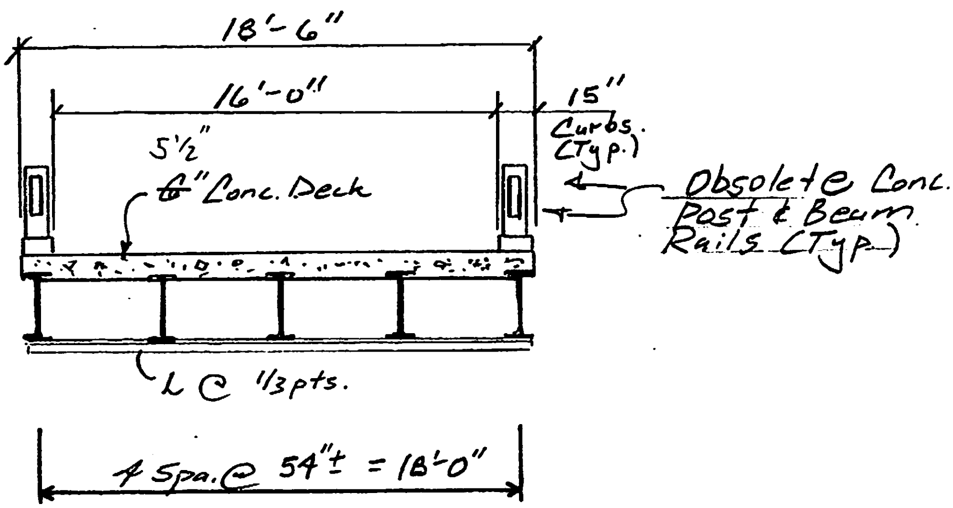
LEGEND

O Span Numbers

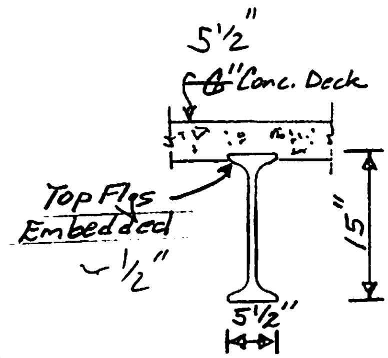
Δ Abutment Numbers

SIDE VIEW

(Looking South)



SPAN 1



Stringers

S15x42.9

$S_x = 58.9 in.^3$

TBLRP-LFR Spreadsheet

Simple Span Steel Stringer

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Yoakum (13)	**AADT ®:**	50 — **# of Lanes:** 1
County:	Lavaca (143)	**Truck % (1% MIN):**	1%
Structure # :	AA01-75-001	**EV Daily Crossing:**	1 — **(1 or 10)** One Direction
Location:	CR 280 Over Ponton Creek	**Year Built:**	2005
		Stringer Descr:	S15x42.9 Interior Steel Stringer

Stringer Inputs

DATA INPUT TABLE	
Span ID:	Span 1 (North Span)
Span Length (ft):	18.00
Span Bearing Length Deduct (ft):	0.00
F_y (ksi):	36.0
Stringer Spacing (ft):	4.50
Misc. Comp Dead Load per Beam (k/ft):	0.000
Misc. Non-Comp Dead Load per Beam (k/ft):	0.000
Top Cover Plate Width (in):	0.000
Top Cover Plate Thickness (in):	0.000
Bottom Cover Plate Width (in):	0.000
Bottom Cover Plate Thickness (in):	0.000
Bottom Flange Unbraced Length, $L_{b\text{-}b}$ (ft):	6.00
Top Flange Unbraced Length, $L_{b\text{-}t}$ (ft):	0.00
DECK INPUTS	
Import Values from Defined Deck Module:	No Deck Import
Deck Type:	Concrete Deck
Deck Thickness (in):	5.500
Composite Action (Y/N):	N
f'c (ksi):	0.5
Slab Embedment (in):	0.500
Deck Weight (ksf):	0.069
Fill Weight (ksf):	0.000
Wearing Surface Weight (ksf):	0.000
Misc. Loads (ksf):	0.000

STRINGER PROPERTIES		
Standard Beam Designation:	S15X42.9	
Rolled Section Depth (in):		15.000
Web Thickness (in):		0.411
Flange Width (in):		5.500
Top Flange Thickness (in):		0.622
Bottom Flange Thickness (in):		0.622
Compact Override (Y/N): Compact — Fillet Radius (in):		0.280
Section Modulus (in^3):		59.48
LIVE LOAD FACTORS		
Deck Type for LLDF:	Concrete Deck	
Stringer Location:	Interior	
	Calculated	Override
LLDF Calc = S /	7.0	
LL Moment Distribution Factor:	0.64	
EV_2 Operating LL Factor:	1.30	
EV_3 Operating LL Factor:	1.30	
Impact Factor (I):	1.30	

Analysis

Stringer Capacity (C_U)	
C_U =	207.3 *k-ft*
C_{serv} =	142.8 *k-ft*
Dead Load Moments (M_{DL})	
$M_{DL} = (1/8) * w_{DL} * L^2$	*k-ft*
M_{deck} =	12.5
M_{beam} =	1.7
$M_{misc\ comp\ DL}$ =	0.0
$M_{misc\ non\text{-}comp\ DL}$ =	0.0
$M_{fill/wearing\ surface}$ =	0.0
M_{DL} =	14.3

Live Load Moments (M_{LL})			
Distributed Live Loads			
	k-ft		*k-ft*
M_{LL} HS:	60.2	M_{LL} T3:	50.5
M_{LL} H:	60.2	M_{LL} T3S2:	46.1
M_{LL} SU_4:	58.3	M_{LL} T3-3:	41.6
M_{LL} SU_5:	59.8	M_{LL} NRL:	61.6
M_{LL} SU_6:	61.6	M_{LL} EV_2:	63.0
M_{LL} SU_7:	61.6	M_{LL} EV_3:	92.1

Additional Notes

€ - AASHTO 10.57 (Serviceability) Controls Ratings
¥ - Based on H-20 Rating
£ - AASHTO 10.57 (Serviceability) Controls Ratings

€ HS Ratings			
HS Inventory:	HS 25.6	RF= 1.28	
HS Operating:	HS 42.8	RF= 2.14	
¥£ H RATING			
H Inventory:	H 25.6	RF= 1.28	
H Operating:	H 42.8	RF= 2.14	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	2.21	**TYPE 3:**	2.54
SU_5 Operating:	2.15	**TYPE 3S2:**	2.79
SU_6 Operating:	2.09	**TYPE 3-3:**	3.09
SU_7 Operating:	2.09	**NRL:**	2.09
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	2.30	**EV_3 Operating:**	1.58

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Stringer (Simple)

Inputs

Span Length:	18.00 ft	Standard Beam Designation:	S15x42.9
Span Bearing Length Deduct:	0.00 ft	Rolled Section Depth:	15.000 in
F_y :	36.0 ksi	Web Thickness:	0.411 in
Stringer Spacing:	4.50 ft	Flange Width:	5.500 in
Misc. Comp Dead Load per Beam:	0.000 klf	Top Flange Thickness:	0.622 in
Misc. Non-Comp Dead Load per Beam:	0.000 klf	Bottom Flange Thickness:	0.622 in
Top Cover Plate Width:	0.000 in	Fillet Radius:	0.280 in
Top Cover Plate Thickness:	0.000 in	Deck Type for LLDF:	Concrete Deck
Bottom Cover Plate Width:	0.000 in	Stringer Location:	Interior
Bottom Cover Plate Thickness:	0.000 in	LL Moment Distribution Factor:	0.64
		EV2 Operating LL Factor:	1.30
Deck Type:	Concrete Deck	EV3 Operating LL Factor:	1.30
Deck Thickness:	5.500 in	Impact Factor:	1.30
Composite Action (Y/N):	N	Bot. Flange Unbraced Length:	6.00 ft
f'_c:	0.5 ksi	Top Flange Unbraced Length:	0.00 ft
Slab Embedment:	0.500 in		
Deck Weight:	0.069 ksf		
Fill Weight:	0.000 ksf		
Wearing Surface Weight:	0.000 ksf		
Misc. Loads:	0.000 ksf		

Capacity

C_u =	F_y*Z =	36.0 ksi * 69.1 in^3 * (1 ft / 12 in)	=	207.3 k-ft
C_{serv} =	0.8*F_y*S_{xncmin} =	0.8 * 36.0 ksi * 59.48 in^3 * (1 ft / 12 in)	=	142.8 k-ft

Dead Load Moments

Deck + Misc. Deck Loads =	(0.069 ksf + 0.000 ksf) * 4.5 ft	=	0.309 klf
Beam =	(12.71 in^2 * (1 ft^2 / 144 in^2)) * 0.490 kcf	=	0.043 klf
Misc Non-Comp Dead Load on Stringer		=	0.000 klf
Misc Comp Dead Load on Stringer		=	0.000 klf
Fill/Wearing Surface =	(0.000 ksf + 0.000 ksf) * 4.5 ft	=	0.000 klf
Total =	0.309 klf + 0.043 klf + 0.000 klf + 0.000 klf + 0.000 klf	=	0.352 klf
Dead Load Moment (M_{DL}) =	(0.352 klf * (18.00 ft - 0 ft)^2) / 8	=	14.3 k-ft

Live Load Moments

From Live Load Moments Worksheet (Without Impact)	=	72.0 k-ft
Distribution Factor (Single Lane)	=	0.643
HS Moment (one line of wheels) (Without Impact)	=	46.3 k-ft

Rating Factors

Ultimate Capacity

HS-20 INV RF =	(207.3 ft-k - 1.3 * 14.3 ft-k) / (2.17 * 46.3 ft-k * 1.3 (IM))	=	1.45
			HS 28.9
HS-20 OPR RF =	(207.3 ft-k - 1.3 * 14.3 ft-k) / (1.3 * 46.3 ft-k * 1.3 (IM))	=	2.41
			HS 48.3

Serviceability

HS-20 INV RF =	(142.8 ft-k - 14.3 ft-k) / (5 * 46.3 ft-k * 1.3 (IM) / 3)	=	1.28
			HS 25.6 <<<
HS-20 OPR RF =	((142.8 ft-k - 14.3 ft-k) / (46.3 ft-k * 1.3 (IM)))	=	2.14
			HS 42.8 <<<

Note: Values above are rounded (not all decimals shown).

Section 11: Steel Stringer (Continuous)

Preface: The Steel Stringer (Continuous) module is similar to the Steel Stringer (Simple) module in that many of the inputs are the same, except that the continuous module requires additional inputs and section checks with the inclusion of negative moment. With the addition of inputs, this module is split between two pages with page 1 showing the Analysis and page 2 becoming the setup for the inputs. The User Guide for Steel Stringer (Continuous) will detail the inputs on page 2 as they appear first.

1. **DECK INPUTS**
    a. ***Import Values from Defined Deck Module*** – Select a deck module from the drop-down list to import previously input deck dead load info.
        i. The deck modules that aren't in use will not be displayed in the drop-down list.
        ii. Select 'No Deck Import' to define a new deck and dead loads.
        iii. Deck modules that are not completely filled out may not import the desired loads.
    b. ***Deck Type*** – Select the Deck Type to use for the analysis.
        i. This is automatically filled in when values are imported. This cell is available to edit if 'No Deck Import' is selected.
        ii. Deck Type Options:
            1. 'Concrete Deck'
            2. 'Steel Corrugated Deck'
            3. 'Steel Plate Deck'
            4. 'Steel Open Grid Deck'
            5. 'Timber Deck'
    c. ***Deck Designation [Steel Corrugated Deck, Steel Open Grid Deck only]*** – Select the deck designation from the drop down. This will calculate the Deck Weight field.
        i. If the desired deck designation is not in the drop-down, type in the designation name and the Deck Weight input will have to be manually calculated.
    d. ***Deck Thickness (in) [Concrete Deck, Steel Plate Deck, Timber Deck only]*** – Input the deck thickness.
        i. ***Deck Weight (ksf)*** below will automatically calculate based upon the standard material unit weights of the selected deck type.
    e. ***Composite Action (Y/N) [Concrete Deck Only]*** – Select 'Y' if shear studs are present in the manner that creates composite action with the deck, otherwise select 'N'.
    f. ***f'c (ksi) [Concrete Deck Only]*** – Enter the compressive strength of the concrete deck. This value is recommended based upon the date built, as seen in *Appendix A*.
    g. ***Slab Embedment (in) [Concrete Deck Only]*** – Some steel bridge structures have been built with the top flange of the stringer embedded in the slab. The measurement is from the bottom of the slab to the top of the flange. If the plans show a haunch over the top of the beam at midspan, the depth may be entered as a negative embedment.
    h. ***Deck Weight (ksf)*** – Value imported from deck module or calculated based on deck thickness input.
        i. This cell can be overwritten at the Engineer's discretion.
    i. ***Fill Weight (ksf)*** – Input the weight of fill acting on the deck.

j. ***Wearing Surface Weight (ksf)*** – Input the weight of wearing surface acting on the deck.
k. ***Misc. Loads (ksf)*** – Input any additional deck dead loads to be included.

2. **LIVE LOAD FACTORS**
   a. ***Deck Type for LLDF*** – Select the deck type to calculate the corresponding live load distribution factors (LLDF). In most cases it will match the deck type.
      i. For Steel Open Grid Decks and Nail/Glue Laminated Timber decks, the deck thickness is needed for the LLDF.
   b. ***Stringer Location*** – Select interior or exterior stringer.
      i. For exterior stringers, the LLDF must be calculated by the user and input in the Override column.
   c. ***LLDF Table*** – This table shows the calculated LLDFs (*AASHTO Table 3.23.1*) and the Impact Factor (IM) calculated as 1 + (50 / (Length + 125)) < 1.3. An override column is provided for each span for use at the Engineer's discretion.
3. **DATA INPUT TABLE**
   a. ***Number of Continuous Spans -*** Select number of continuous spans to be load rated between 2 and 5.
   b. ***Modulus of Elasticity, E (ksi) –*** Input the modulus of elasticity for the steel stringers.
   c. ***Span Length (ft) –*** Input the length for each continuous span.
   d. ***Span Bearing Length Deduct (ft) –*** This is the portion of the overall span located at each end of the span that is between the centerline of the bearing and the centerline of the bent. The value to be entered is the sum of these two described end portions of the span, measured along the centerline of the roadway. The spreadsheet subtracts this value from the Span Length to calculate the effective flexural length of the steel stringer. See Section 10: Steel Stringer (Simple), *Figure 9: Bearing Length Deduct* for reference.
   e. ***Stringer Spacing (ft) –*** Input the stringer spacing from centerline to centerline for each continuous span.
   f. ***Misc. Comp Dead Load per Beam (k/ft) –*** Input the miscellaneous composite dead load per beam. These are loads that were applied after a composite deck is in place. This includes any railing, sidewalks, median, and curbs placed on the composite section.
      i. Do not input miscellaneous composite dead loads if the deck is non-composite.
      ii. If the user inputs a Misc. Comp Dead Load when the deck is non-composite, the dead load value will be considered as a Non-Comp Dead Load along the beam.
   g. ***Misc. Non-Comp Dead Load per Beam (k/ft) –*** Input the miscellaneous non-composite dead load per beam. These are for permanent loads beyond the self-weight applied to the beam before the slab is cast. This should include the weight of diaphragms, if any. Calculate this load per ft per beam by taking the total non-composite dead load for the entire span, in kips, and dividing it by the total length of all stringers on the entire span.
   h. ***F_y (ksi) –*** Input the yield stress of the steel stringer. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.

i. ***Standard Beam Designation*** – Select a beam designation from the dropdown list.
    i. The dropdown list has been compiled from the AISC publication Iron and Steel Beams 1873 to 1972, otherwise known as *Historical Record, Dimensions and Properties, Rolled Shapes, Steel and Wrought Iron Beams & Columns, As Rolled in U.S.A., Period 1873 to 1972, With Sources as Noted*, compiled and edited by Herbert W. Ferris. The dropdown list also consists of the HP, S, and W-Shapes as provided by the AISC Shapes Database (V16.0).
    ii. The selected designation will populate the section dimensions below.
    iii. This designation/section dimensions are for *the typical original stringer section*. Any change in section such as cover plates or section loss will be included later in Section Checks 1 and 2.
    iv. A new stringer designation can be created by inputting all of the section dimensions.
        1. ***Rolled Section Depth (in)*** – Input the rolled section depth of the stringer.
        2. ***Web Thickness (in)*** – Input the stringer web thickness.
        3. ***Flange Width (in) –*** Input the stringer flange width.
        4. ***Top Flange Thickness (in) –*** Input the stringer top flange thickness.
        5. ***Bottom Flange Thickness (in) –*** Input the stringer bottom flange thickness.
        6. ***Fillet Radius (in) –*** Input the fillet radius of the stringer.
        7. ***Moment of Inertia (in^4)*** – Calculated from the section specified above including if composite with deck. Cannot be manually input.
        8. ***Compact Override (Y/N) –*** Input ‘Y’ to analyze the member as compact when the provided geometry states otherwise.
            a. If this option is selected, please document in the Additional Notes the justification for analyzing the member as compact.
            b. If the member is compact given the provided geometry, this input will be locked from editing.

4. **RUN CONTINUOUS STRINGER ANALYSIS**
    a. Push the ‘Run Continuous Stringer Analysis’ button when all information in Deck Inputs, Live Load Factors, and Stringer Inputs have been input. Validation checks will run to ensure data was input correctly and a message box will notify the user of critical errors.
5. **SECTION CHECKS 1 & 2**
    a. The section checks are provided for the user to select 1 or 2 locations per span to determine the controlling moment capacity and load rating. If the section varies from the original section, has section loss, or includes cover plates at the selected location, these dimensions should be filled in as such, otherwise the section dimensions would match the inputs of the Original Stringer Section. Two Section Locations are provided per span so both a positive and negative moment section can be included. The identified section locations are to be selected at the Engineer’s discretion.

b. ***Section Location*** – Select section by percent of span (in tenths) in each span to determine the controlling moment capacity of the stringer.

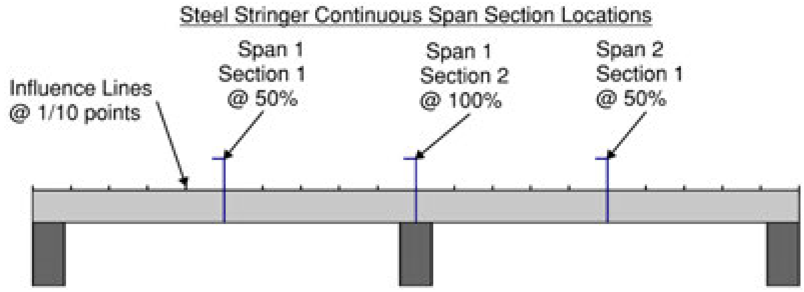


Figure 10: Steel Stringer Continuous Section Locations

c. ***Web Thickness (in)*** – Input the stringer web thickness at section location identified.
d. ***Flange Width (in) –*** Input the stringer flange width at section location identified.
e. ***Top Flange Thickness (in) –*** Input the stringer top flange thickness at section location identified.
f. ***Bottom Flange Thickness –*** Input the stringer bottom flange thickness at section location identified.
g. ***Top Cover Plate Width (in)*** – Input the top cover plate width if present at section location identified.
h. ***Top Cover Plate Thickness (in)*** – Input the top cover plate thickness if present at section location identified.
i. ***Bottom Cover Plate Width (in)*** - Input the bottom cover plate width if present at section location identified.
j. ***Bottom Cover Plate Thickness (in)*** – Input the bottom plate thickness if present at section location identified.
k. ***Section Modulus, (S_x)*** – S_x is calculated from the new section and cannot be manually input.

6. **Analysis**

TBLRP-LFR estimates the live load moments for continuous systems (stringers, girders, etc) by using influence lines. The influence lines are calculated using Muller-Breslau's principle, see *Appendix F.* Each element in the continuous system is divided in ten (10) segments. Once the element is segmented, an influence line for each section at the end of each segment is calculated, ten (10) per segment. For example, a three-span continuous system will have a total of 30 segments and 29 sections. The sections at the exterior supports are not considered. The shared section between elements is considered only once. In this example, 29 influence lines will be computed.

TBLRP-LFR includes 12 standard trucks, H20, HS20, SHVs (4), EVs (2), T3, T3S2, T3-3, and NRL for estimating the live load moments acting in the continuous span model. For each truck, the live load moment at each section is estimated from its influence line by multiplying each truck axle's weight times the corresponding influence line ordinate at the location of each truck axle as it moves along each span in the model. These values are tabulated and used to estimate the maximum live load moment at each section.

The load rating factors at each section are computed and the controlling factors are reported.

a. ***Stringer Capacity at Section Checks***
    i. Presents the calculated controlling moment capacities at each section location defined. The capacity is determined to be (+/-) based on the M_{LL} present at that location.
    ii. See the flowchart in *Appendix C* for determining controlling moment capacities of non-hybrid, unstiffened, steel I-beams and plate girders according to the provisions of *AASHTO 10.48* through *10.50*.
        1. Per *AASHTO 10.48.3*, a transition (straight line interpolation) is allowed between *Eq. 10-92* and *Eq. 10-98* as long as the web thickness always satisfies *Eq. 10-94*.

b. ***(+MDL) and Distributed (+MLL) at Controlling Location***
    i. The controlling location for positive moments is shown in the table. The table informs users of the controlling span, and the location along the span where the controlling rating factors are derived from.

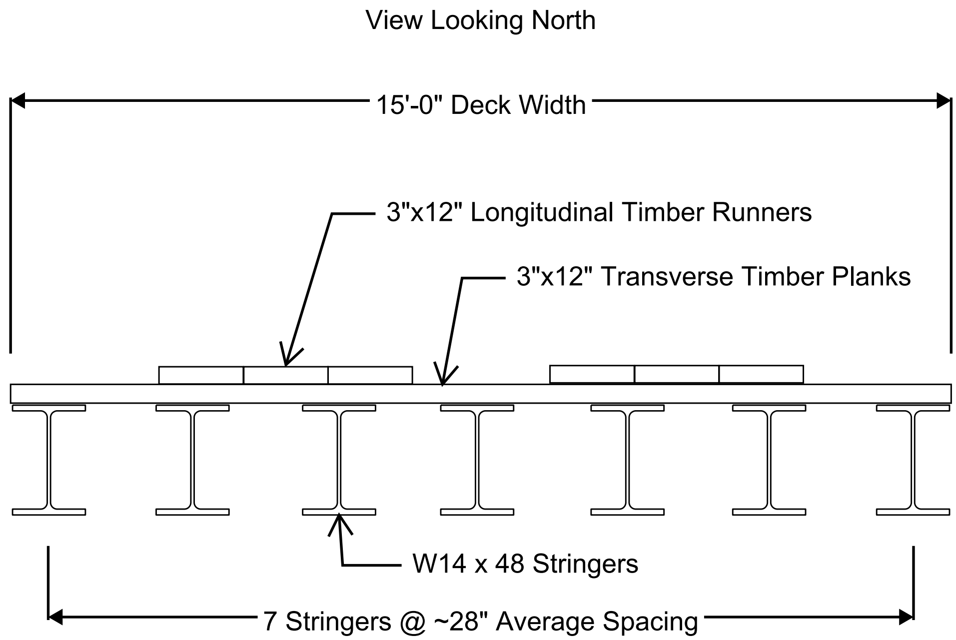
c. ***(-MDL) and Distributed (-MLL) at Controlling Location***
    i. The controlling location for negative moments is shown in the table. The table informs users of the controlling span, and the location along the span where the controlling rating factors are derived from.

General Notes:

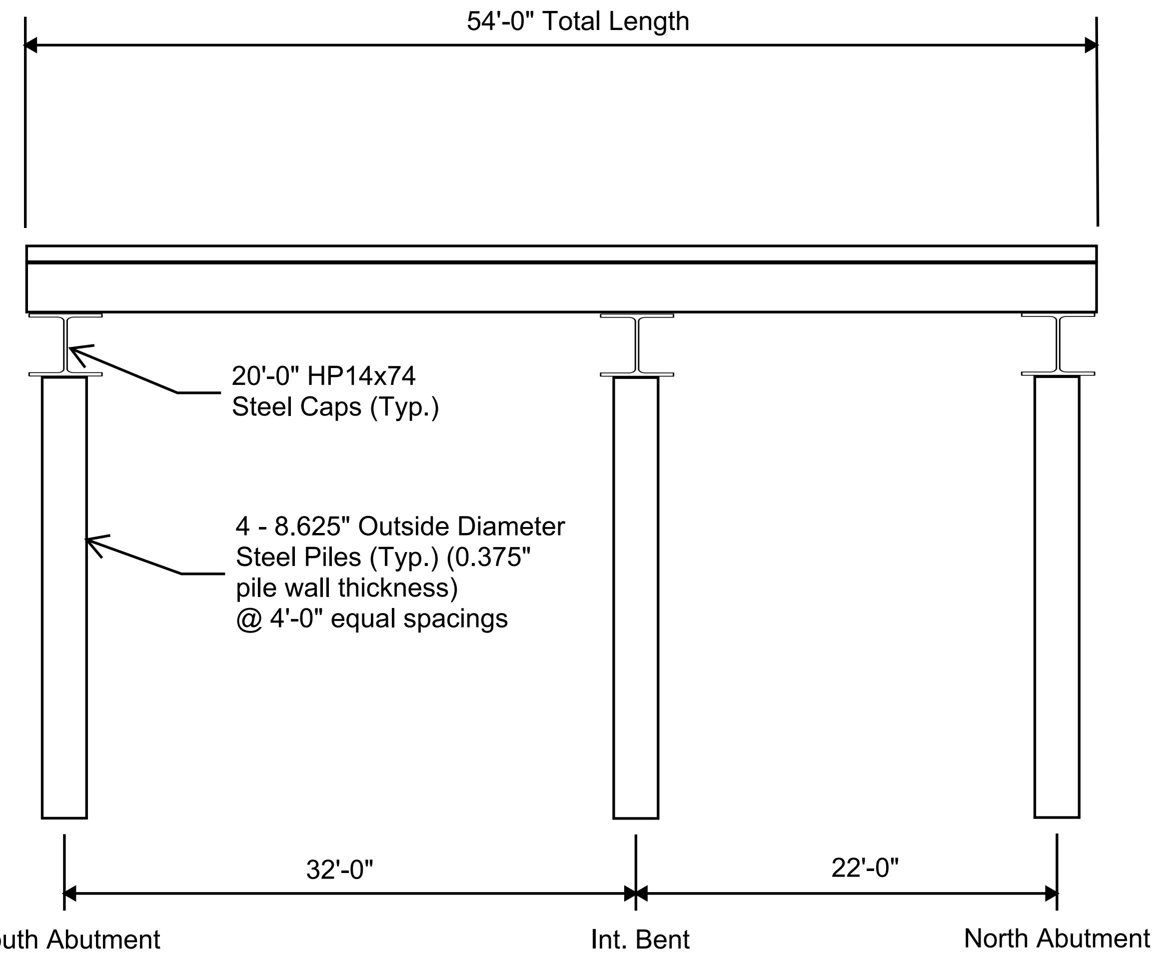
- Changing any of the inputs in the Deck Inputs, Live Load Factors, or Stringer Inputs tables will cause the analysis results to delete. The analysis will then need to be re-run.
- The 'Section Locations' can be changed at any time and do not affect the analysis.
- Full analysis results are shown in the table located at AH80. Values are in k-in.
- Rating factor calculations are shown in the table located at AW80 for each defined section.

Below sketch for example purposes only.

District XX County XXX Con. Sec. XXXX-XX Structure XXX Route Roadway Feature Crossed Stream



Notes:
Stringers are 36 ksi steel
Caps are 36 ksi steel
Piles are 35 ksi steel



TBLRP-LFR Spreadsheet

Continuous Span Steel Stringer

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District: Tyler (10)	**AADT ®:** 50	**# of Lanes:**	1
County: Anderson (001)	**Truck % (1% MIN):** 1%		
Structure # : CCCC-SS-SSS	**EV Daily Crossing:** 1	**(1 or 10)** One Direction	
Location: xx Over xx	**Year Built:** 2000		
	Stringer Descr: W14x48 Interior Steel Continuous Stringer		

Analysis

Stringer Capacity (C_U) at Section Checks

Span	% span	k-ft
1	40%	235.2
1	100%	-235.2
2	60%	235.2
2	10%	-235.2

Stringer Capacity (C_{serv}) at Section Checks

Span	% span	k-ft
1	40%	168.6
1	100%	-168.6
2	60%	168.6
2	10%	-168.6

($+M_{DL}$) and Distributed ($+M_{LL}$) at Controlling Location

	Span	% span	$+M_{DL}$ k-ft	$+M_{LL}$ k-ft
HS:	1	40%	8.9	94.0
SU_4:	1	40%	8.9	91.1
SU_5:	1	40%	8.9	96.6
SU_6:	1	40%	8.9	104.8
SU_7:	1	40%	8.9	110.1
EV_2:	1	40%	8.9	91.0
EV_3:	1	40%	8.9	139.4
T3:	1	40%	8.9	77.4
T3S2:	1	40%	8.9	73.4
T3-3:	1	40%	8.9	60.4
NRL:	1	40%	8.9	112.6

($-M_{DL}$) and Distributed ($-M_{LL}$) at Controlling Location

	Span	% span	$-M_{DL}$ k-ft	$-M_{LL}$ k-ft
HS:	1	100%	-10.8	-74.7
SU_4:	1	100%	-10.8	-61.8
SU_5:	1	100%	-10.8	-69.1
SU_6:	1	100%	-10.8	-77.5
SU_7:	1	100%	-10.8	-84.1
EV_2:	1	100%	-10.8	-62.0
EV_3:	1	100%	-10.8	-95.8
T3:	1	100%	-10.8	-54.0
T3S2:	1	100%	-10.8	-65.9
T3-3:	1	100%	-10.8	-54.7
NRL:	1	100%	-10.8	-84.9

Additional Notes

€ - AASHTO 10.57 (Serviceability) Controls Ratings

¥ - Based on H-20 Rating

£ - AASHTO 10.57 (Serviceability) Controls Ratings

€ HS Ratings			
HS Inventory:	HS 20.4	RF= 1.02	
HS Operating:	HS 34.0	RF= 1.70	
¥£ H RATING			
H Inventory:	H 23.5	RF= 1.17	
H Operating:	H 39.2	RF= 1.96	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	1.76	**TYPE 3:**	2.07
SU_5 Operating:	1.66	**TYPE 3S2:**	2.18
SU_6 Operating:	1.53	**TYPE 3-3:**	2.65
SU_7 Operating:	1.45	**NRL:**	1.42
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.89	**EV_3 Operating:**	1.23

See Formula 6-1a (MCEB) for the general Rating Formula.

TBLRP-LFR Spreadsheet

Continuous Span Steel Stringer

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Tyler (10)	**AADT ®:**	50 **# of Lanes:** 1
County:	Anderson (001)	**Truck % (1% MIN):**	1%
Structure # :	CCCC-SS-SSS	**EV Daily Crossing:**	1 **(1 or 10)** One Direction
Location:	xx Over xx	**Year Built:**	2000
		Stringer Descr:	W14x48 Interior Steel Continuous Stringer

Input Tables

DECK INPUTS	
Import Values from Defined Deck Module:	No Deck Import
Deck Type:	Timber Deck
Deck Thickness (in):	3.000
Deck Weight (ksf):	0.013
Fill Weight (ksf):	
Wearing Surface Weight (ksf):	0.013
Misc. Loads (ksf):	

LIVE LOAD FACTORS					
Deck Type for Live Loads:	Timber Plank				
Stringer Location:	Interior				
	LLDF S/	LLDF	Override	IM	Override
Span 1:	4	0.58		1.30	
Span 2:	4	0.58		1.30	

DATA INPUT TABLE

Number of Continuous Spans: 2   Modulus of Elasticity, E (ksi): 29000.0

	Span ID:	**1**	**2**
	Span Length (ft):	32.00	22.00
	Span Bearing Length Deduct (ft):	1.00	0.50
	Stringer Spacing (ft):	2.33	2.33
	Misc. Non-Comp Dead Load per Beam (k/ft):		
	Misc. Comp Dead Load per Beam (k/ft):		
	F_y (ksi):	36.0	36.0
	Standard Beam Designation:	W14X48	W14X48
ORIGINAL STRINGER SECTION	Rolled Section Depth (in):	13.800	13.800
	Web Thickness (in):	0.340	0.340
	Flange Width (in):	8.030	8.030
	Top Flange Thickness (in):	0.595	0.595
	Bottom Flange Thickness (in):	0.595	0.595
	Fillet Radius (in):	0.580	0.580
	Moment of Inertia (in^4):	484.67	484.67
	Compact Section Override (Y/N):	Compact	Compact

The continuous analysis for dead and live loads is run based on the original stringer section and composite section if applicable. The below inputs are for capacity checks.

Run Continuous Stringer Analysis

SECTION CHECK 1		Section Location:	40%	60%
		Web Thickness (in):	0.340	0.340
		Flange Width (in):	8.030	8.030
		Top Flange Thickness (in):	0.595	0.595
		Bottom Flange Thickness (in):	0.595	0.595
	Top Cover Plate	Width (in):		
		Thickness (in):		
	Bottom Cover Plate	Width (in):		
		Thickness (in):		
		Section Modulus, S_x (in^3):	70.24	70.24

SECTION CHECK 2		Section Location:	100%	10%
		Web Thickness (in):	0.340	0.340
		Flange Width (in):	8.030	8.030
		Top Flange Thickness (in):	0.595	0.595
		Bottom Flange Thickness (in):	0.595	0.595
	Top Cover Plate	Width (in):		
		Thickness (in):		
	Bottom Cover Plate	Width (in):		
		Thickness (in):		
		Section Modulus, S_x (in^3):	70.24	70.24

Steel Stringer (Continuous)

Inputs

Number of Continuous Spans:	2	
Modulus of Elasticity, E (ksi):	29000	
Span ID:	1	2
Span Length (ft):	32.00	22.00
Span Bearing Length Deduct (ft):	1.00	0.50
Stringer Spacing (ft):	2.33	2.33
Misc. Non-Comp Dead Load per Beam (klf):	0.000	0.000
Misc. Comp Dead Load per Beam (klf):	0.000	0.000
F_y (ksi):	36.0	36.0
Standard Beam Designation:	W14x48	W14x48
ORIGINAL STRINGER SECTION		
Rolled Section Depth (in):	13.800	13.800
Web Thickness (in):	0.340	0.340
Flange Width (in):	8.030	8.030
Top Flange Thickness (in):	0.595	0.595
Bottom Flange Thickness (in):	0.595	0.595
Fillet Radius (in):	0.580	0.580
Moment of Inertia (in^4):	484.67	484.67

Import Values from Defined Deck Module:	No Deck Import
Deck Type:	Timber Deck
Deck Thickness:	3.000 in
Deck Weight:	0.013 ksf
Fill Weight:	0.000 ksf
Wearing Surface Weight:	0.013 ksf
Misc. Loads:	0.000 ksf

Deck Type for Live Loads: Timber Plank
Stringer Location: Interior

	LLDF S/	LLDF	IM
Span 1:	4	0.58	1.30
Span 2:	4	0.58	1.30

Capacity

C_u =	F_y*Z =	36.0 ksi * 78.4 in^3 * (1 ft / 12 in)	=	235.2 ft-k
C_{serv} =	0.8*F_y*S_{xncmin} =	0.8 * 36.0 ksi * 70.2 in^3 * (1 ft / 12 in)	=	168.6 ft-k

Dead Loads

			Span 1	Span 2	
Deck + Misc. Deck Loads =	(0.013 ksf + 0.000 ksf) * 2.33 ft	=	0.029	0.029	klf
Beam =	(14.13 in^2 * (1 ft^2 / 144 in^2)) * 0.490 kcf	=	0.048	0.048	klf
Misc Non-Comp Dead Load on Stringer		=	0.000	0.000	klf
Misc Comp Dead Load on Stringer		=	0.000	0.000	klf
Fill/Wearing Surface =	(0.013 ksf + 0.000 ksf) * 4.8 ft	=	0.030	0.030	klf
Total		=	0.108	0.108	klf

Dead Load and Live Load Moments

TBLRP-LFR estimates the dead and live load moments for continuous systems (stringers, girders, etc) by using influence lines. See Appendix A for more information.

	Span 1		Span 2		
Distribution Factor (multi-lane)	0.58		0.58		
Impact	1.30		1.30		
	Section 1	Section 2	Section 1	Section 2	
	40%	100%	60%	10%	
(Minus Impact) $Moment_{LL - HS-20}$	124.1	-98.7	74.8	-83.3	ft-k
(Minus Impact) $Moment_{Distributed}$	72.3	-57.5	43.6	-48.5	ft-k
$Moment_{Dead Load}$	8.9	-10.8	1.9	-7.4	ft-k

Rating Factors

Positive Moment

HS-20 INV RF =	(235.2 k-ft - 1.3 * 8.9 k-ft)/(2.17 * 72.3 k-ft * 1.3)	=	1.10	HS 21.9	
HS-20 OPR RF =	(235.2 k-ft - 1.3 * 8.9 k-ft)/(1.3 * 72.3 k-ft * 1.3)	=	1.83	HS 36.6	
HS-20 INV RF_{SERV} =	(168.6 k-ft - 8.9 k-ft)/(5 / 3 * 72.3 k-ft * 1.3)	=	1.02	**HS 20.4**	<<<
HS-20 OPR RF_{SERV} =	(168.6 k-ft - 8.9 k-ft)/(72.3 k-ft * 1.3)	=	1.70	**HS 34.0**	<<<

Negative Moment

HS-20 INV RF =	(235.2 k-ft - 1.3 * 10.8 k-ft)/(2.17 * 57.5 k-ft * 1.3)	=	1.36	HS 27.2
HS-20 OPR RF =	(235.2 k-ft - 1.3 * 10.8 k-ft)/(1.3 * 57.5 k-ft * 1.3)	=	2.28	HS 45.6
HS-20 INV RF_{SERV} =	(168.6 k-ft - 10.8 k-ft)/(5 / 3 * 57.5 k-ft * 1.3)	=	1.27	**HS 25.4**
HS-20 OPR RF_{SERV} =	(168.6 k-ft - 10.8 k-ft)/(57.5 k-ft * 1.3)	=	2.12	**HS 42.4**

Note: Values above are rounded (not all decimals shown).

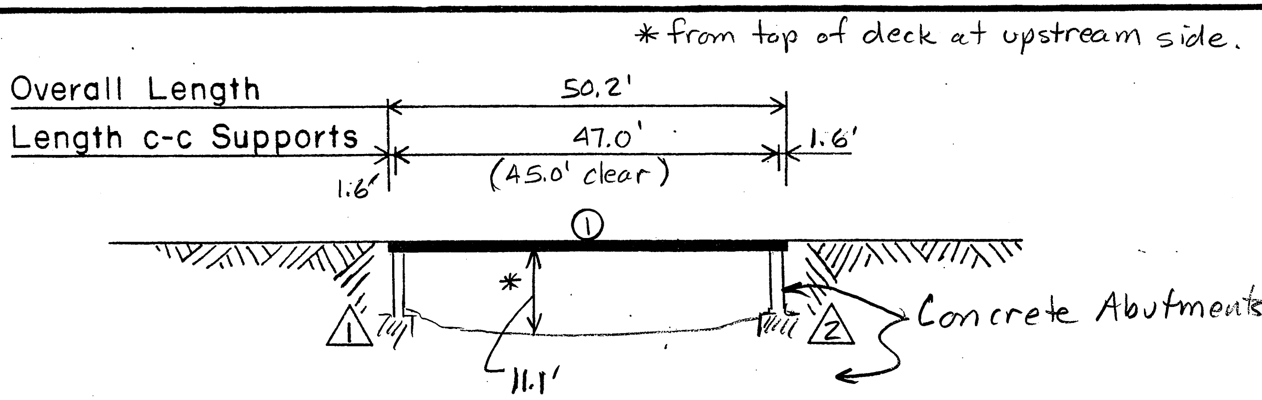
Section 12: Steel Floorbeam

1. **DATA INPUT TABLE**
    a. ***Floorbeam ID*** - The Floorbeam ID should correspond with the floorbeam numbers used on the bridge plans or inventory record.
    b. ***Standard Beam Designation*** – Select a beam designation from the dropdown list.
        i. The dropdown list has been compiled from the AISC publication Iron and Steel Beams 1873 to 1972, otherwise known as *Historical Record, Dimensions and Properties, Rolled Shapes, Steel and Wrought Iron Beams & Columns, As Rolled in U.S.A., Period 1873 to 1972, With Sources as Noted*, compiled and edited by Herbert W. Ferris. The dropdown list also consists of the HP, S, and W-Shapes as provided by the AISC Shapes Database (V16.0).
        ii. The selected designation will populate the section dimensions below.
            1. Each section dimension can be overwritten to be the "remaining section" if section loss is present at the Engineer's discretion.
        iii. A new floorbeam designation can be created by inputting all of the section dimensions.
            1. ***Rolled Section Depth (in)*** – Input the rolled section depth of the floorbeam.
            2. ***Web Thickness (in)*** – Input the floorbeam web thickness.
            3. ***Flange Width (in) –*** Input the floorbeam flange width.
            4. ***Top Flange Thickness (in) –*** Input the floorbeam top flange thickness.
            5. ***Bottom Flange Thickness (in) –*** Input the floorbeam bottom flange thickness.
            6. ***Fillet Radius (in) –*** Input the fillet radius of the floorbeam.
    c. ***Section Modulus, S (in^3)*** – Calculated from the section dimensions, but can be overwritten.
        i. For a non-typical shape, input the moment of inertia calculated from the section dimensions of the non-typical shape.
    d. ***Plastic Section Modulus, Z (in^3)*** – Calculated from the section dimensions, but can be overwritten.
        i. For a non-typical shape, input the plastic section modulus calculated from the section dimensions of the non-typical shape.
    e. ***F_y (ksi) –*** Input the yield stress of the steel floorbeam. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.
    f. ***Is Section Compact***? – Select 'Yes' if the section is compact to use the *Plastic Section Modulus (Zx)* to calculate the ultimate capacity (C_u), otherwise select 'No' to use Section Modulus (Sx).
    g. ***Floorbeam Weight (k/ft)*** – Calculated from the section dimensions, but can be overwritten.
    h. ***Section Loss due to Corrosion (%)*** – Input the section loss of the floorbeam section.
    i. ***Location of Floorbeam within Span*** – Select location of floorbeam.
        i. 'End' floorbeam is located over the abutment.
        ii. 'Intermediate' floorbeam is located within the span.

j. ***Floorbeam Length (Girder Spacing) (ft)*** – Input the floorbeam length between girders.

2. **DATA FROM SUPERSTRUCTURE**
   a. ***Deck Module*** – Select a deck module to import the total deck dead load.
      i. 'Deck Defined in Girder Module' imports the same total deck dead load defined in the girder module.
      ii. 'Steel Deck' uses the same total deck loads defined for the steel deck module.
      iii. 'Timber Deck' uses the same total deck loads defined for the timber deck module.
      iv. 'No Deck Import' allows the user to input a value for the 'Total Dead Load' of the deck.
   b. ***Total Dead Load (ksf)*** – Includes all dead loads on the deck: self-weight of deck, fill, wearing surface, and misc. dead loads.
3. **STRINGER MODULE DATA**
   a. ***Stringer Module 1 & 2*** – Select a stringer module to import the stringer span and weight.
      i. See visuals in *Figure 11: Girder - Floorbeam - Stringer Typical Section* and *Figure 12: Floorbeam Layout and Spacing* in Section 13.
      ii. Selecting a defined stringer module will import the stringer span and weight.
      iii. Selecting 'No Stringer Import' will allow the user to input stringer span and weight.
   b. ***Number of Stringers*** – Input number of stringers between girders.
   c. ***Stringer Spacing (ft)*** – Input spacing between stringers.
4. ***LL Impact Factor (I)*** – Table shows the calculated Impact Factor of 1 + (50 / (Length + 125)) < 1.3
   a. An override is provided for use at the Engineer's discretion.
5. **Analysis**
   a. **Floorbeam Capacity**
      i. The ultimate capacity is calculated as F_y * Z_x * (1 – SL%) if the section is compact.
         1. If not, the capacity is calculated as F_y * S_x * (1 – SL%)
      ii. The serviceability capacity is calculated as 0.8 * F_y * S_x * (1 – SL%)
   b. **Dead Load Moments (MDL)**
      i. ***$M_{deck\ and\ fill}$*** – Calculated by the Total Deck Load (applied by tributary area through each stringer) and applied as point loads on the floorbeam.
      ii. ***$M_{stringers}$*** – Self weight of steel stringers applied as point loads on the floorbeam.
      iii. ***$M_{floorbeam}$*** – Self weight of the floorbeam as input in *Floorbeam Weight*.
   c. ***Live Load Moments (MLL)***
      i. The live load moments are calculated by the following formula for each truck:
         1. Single Lane: $((L – 3)^2 * R) / (2 * L)$
         2. Multi-Lane: $(L – 9 + (2.25 / L)) * R$
            a. L is floorbeam length.
            b. R is the wheel line reaction load.
            c. Formulas based on the *3rd Edition of the Manual for Bridge Evaluation Appendixes D6B and E6B*.
   d. Additional information on the analysis performed can be found to the right of the printed section.

District 13 County 143 Cont.-Sec. AA01-47 Structure 001 Route CR 350

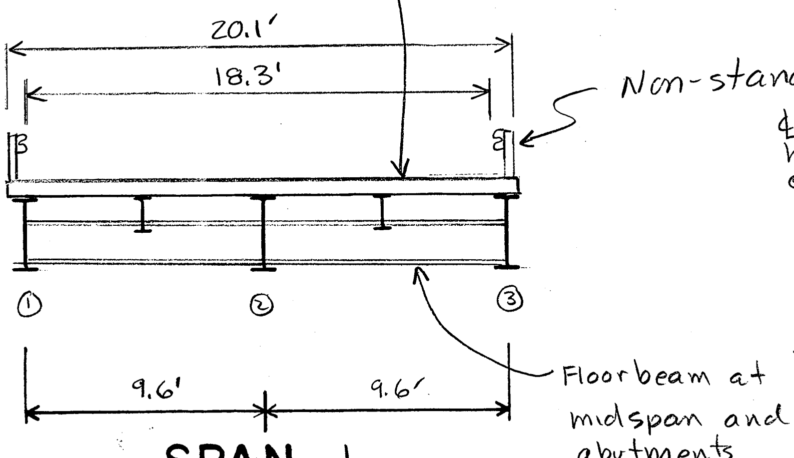


LEGEND

- ○ Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support

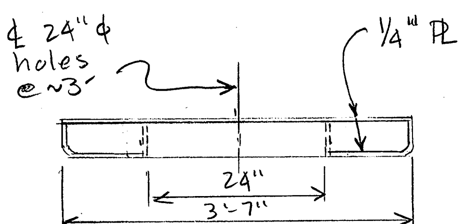
SIDE VIEW

(Looking SOUTH)

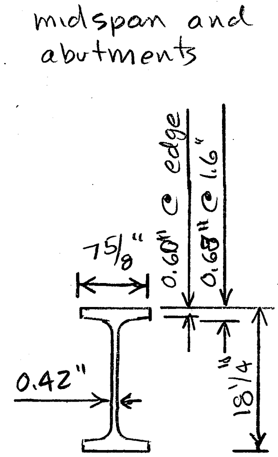


SPAN 1

(Looking West)

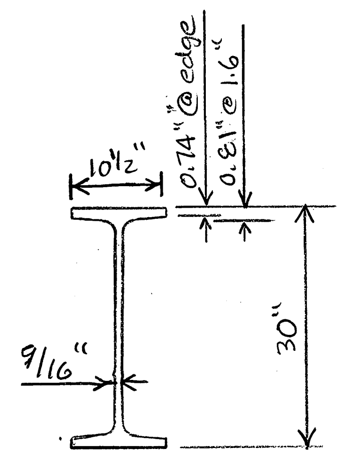


STEEL PLANK DECK



FLOORBEAMS AND INTERMEDIATE STRINGERS

WF 18 x 60 (S = 107.8 in³)



STRINGERS ② & ③

WF 30 x 116 (S = 328 in³)

STRINGER ① has 3/4" flanges with no slope. WF 30 x 108

SPAN

TBLRP-LFR Spreadsheet

Steel Floorbeam

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Yoakum (13)
County:	Lavaca (143)
Structure # :	AA01-47-001
Location:	CR 350 Over Boggy Creek

AADT ®:	50	**# of Lanes:**	1
Truck % (1% MIN):	1%		
EV Daily Crossing:	1	**(1 or 10)** One Direction	
Year Built:	1995		
Floorbeam Descr:	W18x60 Steel Floorbeam		

Floorbeam Inputs

DATA INPUT TABLE	
Floorbeam ID:	2.000
Standard Beam Designation:	W18X60
Rolled Section Depth (in):	18.200
Web Thickness (in):	0.415
Flange Width (in):	7.560
Top Flange Thickness (in):	0.695
Bottom Flange Thickness (in):	0.695
Fillet Radius (in):	0.500
Section Modulus, S_x (in^3):	108.183
Plastic Section Modulus, Z_x (in^3):	123.072
F_y (ksi):	36.0
Is Section Compact?:	Yes
Floorbeam Weight (k/ft):	0.060
Section Loss due to Corrosion (%):	0%
Location of Floorbeam within Span*:	Intermediate
Floorbeam Length (Girder Spacing) (ft):	9.60

**Intermediate: Floorbeam located within Span or over int. bent*

DATA FROM SUPERSTRUCTURE	
Deck Module:	Deck Defined in Girder Module
Total Dead Load (ksf):	0.031
Stringer Module 1:	Continuous Stringer (Span 1)
Span 1 Total Length** (ft):	25.10
Span 1 Stringer Weight (k/ft):	0.060
Span 1 Number of Stringers:	1
Stringer Spacing (ft):	4.80
Stringer Module 2:	Continuous Stringer (Span 2)
Span 2 Total Length** (ft):	25.10
Span 2 Stringer Weight (k/ft):	0.060
Span 2 Number of Stringers:	1
Stringer Spacing (ft):	4.80

***Input the stringer span length between floorbeams*

	Calculated	Override
LL Impact Factor (I):	1.30	

Analysis

Floorbeam Capacity		*k-ft*
C_U =	Fy * Z * (1 - SL%) =	369.2
C_{Serv} =	0.8 * Fy * S * (1 - SL%) =	259.6

Dead Load Moments (M_{DL})	
$M_{DL} = (1/8) * w_{DL} * L^2$	*k-ft*
$M_{deck\ and\ fill}$ =	9.0
$M_{stringers}$ =	3.6
$M_{floorbeam}$ =	0.7
M_{DL} =	13.3

Live Load Moments (M_{LL})	
Single Lane Moments =	$((L-3)^2*R)/(2*L)$
Two-Lane Moments =	(L-9+(2.25/L))*R
	k-ft
H:	40.3
HS:	56.4
SU_4:	49.1
SU_5:	53.2
SU_6:	59.2
SU_7:	63.9
EV_2:	49.0
EV_3:	75.7
T3:	42.8
T3S2:	39.1
T3-3:	35.9
NRL:	66.9

Live load reactions and moments computed based on the 3rd Edition of the Manual for Bridge Evaluation Appendixes D6B and E6B.
Assume floorbeam is fully braced.

Additional Notes

€ - AASHTO 10.57 (Serviceability) Controls Ratings
¥ - Based on H-20 Rating
£ - AASHTO 10.57 (Serviceability) Controls Ratings

€ HS Ratings			
HS Inventory:	HS 40.3	RF= 2.02	
HS Operating:	HS 67.4	RF= 3.37	
¥£ H RATING			
H Inventory:	H 56.4	RF= 2.82	
H Operating:	H 94.2	RF= 4.71	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	3.86	**TYPE 3:**	4.44
SU_5 Operating:	3.57	**TYPE 3S2:**	4.86
SU_6 Operating:	3.21	**TYPE 3-3:**	5.29
SU_7 Operating:	2.97	**NRL:**	2.84
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	3.88	**EV_3 Operating:**	2.51

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Floorbeam

Inputs

Yield Strength (F_y):	36.0	ksi	Total Dead Load from Deck:	0.031	ksf
Standard Beam Designation:	W18x60			Stringer Module 1	
Section Modulus, S_x:	108.183	in^3	Span 1 Total Length:	25.10	ft
Plastic Section Modulus, Z_x:	123.072	in^3	Span 1 Stringer Weight:	0.060	klf
Is section Compact?:	Yes		Span 1 Number of Stringers:	1	
Floorbeam Weight:	0.060	klf	Stringer Spacing:	4.80	ft
Section Loss due to Corrosion (%):	0%			Stringer Module 2	
Location of Floorbeam within Span*:	Intermediate		Span 2 Total Length:	25.10	ft
Floorbeam Length (Girder Spacing):	9.60	ft	Span 2 Stringer Weight:	0.060	klf
			Span 2 Number of Stringers:	1	
			Stringer Spacing:	4.80	ft
			LL Impact Factor:	1.30	

Capacity

C_u =	F_y*Z*(1-SL%) =	36.0 ksi * 123.072 in^3 * (1 - 0.00) * (1 ft / 12 in) =	369.2 k-ft
C_{serv} =	0.8*F_y*S*(1-SL%) =	0.8 * 36.0 ksi * 108.183 in^3 * (1 - 0.00) * (1 ft / 12 in) =	259.6 k-ft

Dead Load Moments

$P_{Deck\ and\ Fill}$ =	Stringer span1 / 2 * Stringer spacing * Deck Dead Load		
$P_{Deck\ and\ Fill:\ Stringer\ Module\ 1}$ =	(25.10 ft / 2) * 4.80 ft * 0.031 ksf	=	1.9 k
$P_{Deck\ and\ Fill:\ Stringer\ Module\ 2}$ =	(25.10 ft / 2) * 4.80 ft * 0.031 ksf	=	1.9 k
$M_{deck\ and\ fill}$ =	P_{st} * a * x / L		
$M_{deck\ and\ fill}$ =	(1.9 k + 1.9 k) * 4.80 ft * (9.60 ft / 2) / 9.60 ft	=	9.0 k-ft
$P_{Stringer}$ =	Stringer span1 / 2 * Stringer Dead Load		
$P_{Stringer:\ stringer\ Module\ 1}$ =	(25.10 ft / 2) * 0.060 ksf	=	0.8 k
$P_{Stringer:\ stringer\ Module\ 2}$ =	(25.10 ft / 2) * 0.060 ksf	=	0.8 k
$M_{stringer}$ =	P_{st} * a * x / L		
$M_{stringer}$ =	(0.8 k + 0.8 k) * 4.80 ft * (9.60 ft / 2) / 9.60 ft	=	3.6 k-ft
$M_{floorbeam}$ =	(0.060 klf * (9.60 ft)^2) / 8	=	0.7 k-ft
M_{DL} =			**13.3 k-ft**

Live Load Moments

Find HS-20 Wheel Line Reaction Loads

Live load reactions and moments computed based on the 3rd Edition of the Manual for Bridge Evaluation Appendixes D6B and E6B.

1st Axle Load =	IF 25.10 ft > 14 ft then: (8 k - 112 k-f t/ 25.10 ft) / 2	=	1.8 k
2nd Axle Load =	Axle placed over floorbeam	=	16 k
3rd Axle Load =	IF 25.10 ft > 14 ft then: (32 k - 448 k-ft/25.10 ft) / 2	=	7.1 k
Total =			24.8 k
Single Lane Moments =	((L-3)^2*R)/(2*L) = ((9.60 ft - 3)^2 * 24.8 k) / (2 * 9.60 ft)	=	56.4 k-ft

Rating Factors

HS-20 INV RF =	(369.2 k-ft - 1.3 * 13.3 k-ft) / (2.17 * 56.4 k-ft * 1.3 (IM))	=	2.21
			HS 44.2
HS-20 OPR RF =	(369.2 k-ft - 1.3 * 13.3 k-ft) / (1.3 * 56.4 k-ft * 1.3 (IM))	=	3.69
			HS 73.9
HS-20 INV RF_{SERV} =	(259.6 k-ft - 13.3 k-ft) / (5 / 3 * 56.4 k-ft * 1.3 (IM))	=	2.02
			HS 40.3 <<<
HS-20 OPR RF_{SERV} =	(259.6 k-ft - 13.3 k-ft) / (56.4 k-ft * 1.3 (IM))	=	3.37
			HS 67.4 <<<

Note: Values above are rounded (not all decimals shown).

Section 13: Steel Girder (Simple)- GFS

1. **DATA INPUT TABLE**
    a. ***Span ID*** - The Span ID should correspond with the span numbers used on the bridge plans or inventory record.
    b. ***Span Length (ft)*** – Input the length of the span.
    c. ***Span Bearing Length Deduct (ft)*** – This is the portion of the overall span located at each end of the span that is between the centerline of the bearing and the centerline of the bent. The value to be entered is the sum of these two described end portions of the span, measured along the centerline of the roadway. The spreadsheet subtracts this value from the Span Length to calculate the effective flexural length of the steel stringer. See *Section 10: Steel Stringer (Simple)*, *Figure 9: Bearing Length Deduct* for reference.
    d. ***F_y (ksi)*** – Input the yield stress of the steel girder. If unknown, this value is recommended based upon the date built, as seen in *Appendix A.*
    e. ***Girder Spacing (ft)*** – Input the girder spacing from centerline to centerline.
    f. ***Misc. Comp Dead Load per Beam (k/ft)*** – Input the miscellaneous composite dead load per beam. These are loads that were applied after a composite deck is in place. This includes any railing, sidewalks, median, and curbs placed on the composite section.
        i. Do not input miscellaneous composite dead loads if the deck is non-composite.
        ii. If the user inputs a Misc. Comp Dead Load when the deck is non-composite, the dead load value will be considered as a Non-Comp Dead Load along the beam.
    g. ***Misc. Non-Comp Dead Load per Beam (k/ft)*** – Input the miscellaneous non-composite dead load per beam. These are for permanent loads beyond the self-weight applied to the beam before the slab is cast. This should include the weight of diaphragms, if any. Calculate this load per ft per beam by taking the total non-composite dead load for the entire span, in kips, and dividing it by the total length of all stringers on the entire span.
    h. ***Top Cover Plate Width (in)*** – Input the top cover plate width if present at midspan.
    i. ***Top Cover Plate Thickness (in)*** – Input the top cover plate thickness if present at midspan.
    j. ***Bottom Cover Plate Width (in)*** – Input the bottom cover plate width if present at midspan.
    k. ***Bottom Cover Plate Thickness (in)*** – Input the bottom plate thickness if present at midspan.
    l. ***Bottom Flange Unbraced Length, Lb-b (ft)*** – Input the unbraced length for the bottom flange.
    m. ***Top Flange Unbraced Length, Lb-t (ft)*** – Input the unbraced length for the top flange.
        i. This module considers the top flange fully braced when in contact with a concrete deck, steel corrugated deck, and a steel plate deck. When one of these deck types are selected in the Deck Inputs below, the program will default the top flange unbraced length to equal 0’ in its analysis in column AJ.

   ii. Research has shown that the beam does not have to be embedded in the deck nor does the deck have to be concrete to provide effective lateral bracing. The following cases will provide effective lateral bracing. The first three cases may be analyzed as fully braced. In the last two cases, the beam should be analyzed with an unbraced length equal to half the span length. In the last case, if the depth of base is substantially greater than 6 inches the beam may be analyzed as fully braced.
      1. Concrete deck cast on top of the compression flange.
      2. Corrugated metal deck. The deck sections should be interconnected adequately to ensure that the deck acts as a unit.
      3. Laminated timber deck.
      4. Timber plank deck with timber runners. Each of the two runners should be about 2 feet wide and the individual runner planks should be securely attached to the deck.
      5. Timber plank deck covered with at least 6 inches of base and asphaltic overlay.
   iii. In all of the above cases, the deck should be in contact with the flange. The deck should be secured to the superstructure at sufficient points to ensure that the entire deck does not shift laterally. Timber plank decks should be evaluated conservatively when used on bending members deeper than about 24 inches.

2. **DECK INPUTS**
   a. ***Import Values from Defined Deck Module*** – Select a deck module from the drop-down list to import previously input deck dead load info.
      i. The deck modules that aren't in use will not be displayed in the drop-down list.
      ii. Select 'No Deck Import' to define a new deck and dead loads.
      iii. Deck modules that are not completely filled out may not import the desired loads.
   b. ***Deck Type*** – Select the Deck Type to use for the analysis.
      i. This is automatically filled in when values are imported.
      ii. Deck Type Options:
         1. 'Concrete Deck'
         2. 'Steel Corrugated Deck'
         3. 'Steel Plate Deck'
         4. 'Steel Open Grid Deck'
         5. 'Timber Deck'
   c. ***Deck Designation [Steel Corrugated Deck, Steel Open Grid Deck only]*** – Select the deck designation from the drop down. This will calculate the Deck Weight field.
      i. If the desired deck designation is not in the drop-down, type in the designation name and the Deck Weight input will have to be manually calculated.
   d. ***Deck Thickness (in) [Concrete Deck, Steel Plate Deck, Timber Deck only]*** – Input the deck thickness.
      i. ***Deck Weight (ksf)*** below will automatically calculate based upon the standard material unit weights of the selected deck type.

e. ***Composite Action (Y/N) [Concrete Deck Only]*** - Select 'Y' if shear studs are present in the manner that creates composite action with the deck, otherwise select 'N'.
f. ***f'c (ksi) [Concrete Deck Only]*** – Enter the compressive stress of the concrete deck. This value is recommended based upon the date built, as seen in *Appendix A*.
g. ***Slab Embedment (in) [Concrete Deck Only] –*** Some steel bridge structures have been built with the top flange of the stringer embedded in the slab. The measurement is from the bottom of the slab to the top of the flange. If the plans show a haunch over the top of the beam at midspan, the depth must be entered as a negative embedment.
h. ***Deck Weight (ksf)*** – Value imported from deck module or calculated based on deck thickness input.
    i. This cell can be overwritten at the Engineer's discretion.
i. ***Fill Weight (ksf)*** - Input the weight of fill acting on the deck.
j. ***Wearing Surface Weight (ksf)*** – Input the weight of wearing surface acting on the deck.
k. ***Misc. Loads (ksf)*** – Input any additional deck dead loads to be included.
l. ***Girder Trib Width for Deck Dead Loads (ft)*** – Input the girder tributary width for deck dead loads applied directly to the girder.
    i. Dead loads are distributed to the girders by tributary area. Dead loads within the stringer tributary areas will be applied to the girders via the stringers and floorbeams. See *Figure 11: Girder - Floorbeam - Stringer Typical Section* for additional guidance.

3. **GIRDER PROPERTIES**
    a. ***Standard Beam Designation*** – Select a beam designation from the dropdown list.
        i. The dropdown list has been compiled from the AISC publication Iron and Steel Beams 1873 to 1972, otherwise known as Historical Record, Dimensions and Properties, Rolled Shapes, Steel and Wrought Iron Beams & Columns, As Rolled in U.S.A., Period 1873 to 1972, With Sources as Noted, compiled and edited by Herbert W. Ferris. The dropdown list also consists of the HP, S, and W-Shapes as provided by the AISC Shapes Database (V16.0).
        ii. The selected designation will populate the section dimensions below.
            1. Each section dimension can be overwritten to be the "remaining section" if section loss is present at the Engineer's discretion.
        iii. A new stringer designation can be created by inputting all of the section dimensions.
            1. ***Rolled Section Depth (in)*** – Input the rolled section depth of the stringer.
            2. ***Web Thickness (in)*** – Input the stringer web thickness.
            3. ***Flange Width (in)*** – Input the stringer flange width.
            4. ***Top Flange Thickness (in)*** – Input the stringer top flange thickness.
            5. ***Bottom Flange Thickness (in)*** – Input the stringer bottom flange thickness.
            6. ***Fillet Radius (in)*** – Input the stringer fillet radius.
            7. ***Compact Override (Y/N)*** – Input 'Y' to analyze the member as compact when the provided geometry states otherwise.

a. If this option is selected, please document in the Additional Notes the justification for analyzing the member as compact.
b. If the member is compact given the provided geometry, this input will be locked from editing.

8. ***Section Modulus, S (in^3)*** – Calculated from the section dimensions and cannot be overwritten.

iv. For typical member shapes used for analysis, see *Appendix A.*

4. **LIVE LOAD FACTORS**
   a. ***Deck Type for LLDF*** – Select the deck type to calculate the corresponding live load distribution factors (LLDF). In most cases, it will match the deck type.
      i. For Steel Open Grid Decks and Nail/Glue Laminated Timber decks, the deck thickness is needed for the LLDF.
   b. ***Girder Location*** – Select interior or exterior stringer.
      i. For exterior stringers, the LLDF must be calculated by the user and input in the Override column.
5. **LLDF Table** – This table shows the calculated LLDFs (*AASHTO Table 3.23.1*) and the Impact Factor (IM) calculated as 1 + (50 / (Length + 125)) < 1.3. An override column is provided for use at the Engineer's discretion.
6. **FLOORBEAM INPUTS**
   a. ***Distance along Span to First Floorbeam (ft)*** – Input the distance along the girder's span to the first floorbeam. (*Figure 12: Floorbeam Layout and Spacing*)
   b. ***Average Floorbeam Spacings (ft)*** – Input the average floorbeam spacing from the first floorbeam's location. (*Figure 11: Girder - Floorbeam - Stringer Typical Section)*
   c. ***Deck Dead Load (k)*** – Total load of the deck/fill/wearing surface/misc. deck loads calculated as Total Dead Load (ksf) x (Span 1 Total Length/2 x Stringer Spacing [span 1] + Span 2 Total Length 2 x Stringer Spacing [Span 2])
      i. Deck loads are calculated directly from the Floorbeam Module and are not editable.
   d. ***Stringers and Floorbeam Dead Load (k)*** – Total load from the floorbeam and stringers' self-weight.
      i. Stringer and floorbeam loads are calculated directly from the Floorbeam Module and are not editable.
   e. ***Total Point Load to Girder per Floorbeam (k)*** – The calculated total point load applied to the girder at each floorbeam location. Calculated as the sum of Deck Dead Load and Stringers and Floorbeam Dead Load for interior girders and half that for exterior.
   f. ***Number of Point Loads Applied along Girder*** – The number of point loads applied to the girder are based upon Distance along Span to First Floorbeam and Average Floorbeam Spacings inputs.
      i. Floorbeams over abutments are ignored in this analysis.

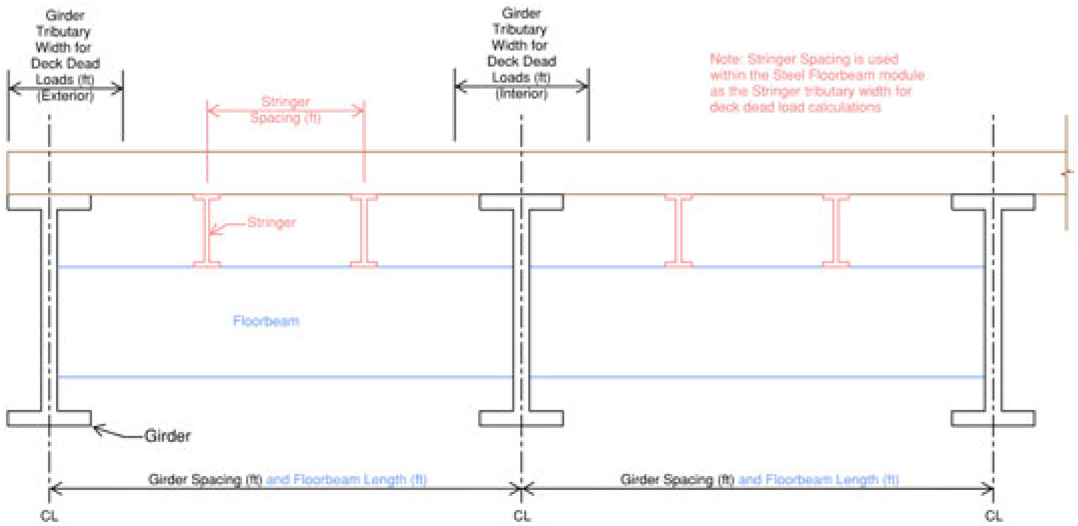


Figure 11: Girder - Floorbeam - Stringer Typical Section

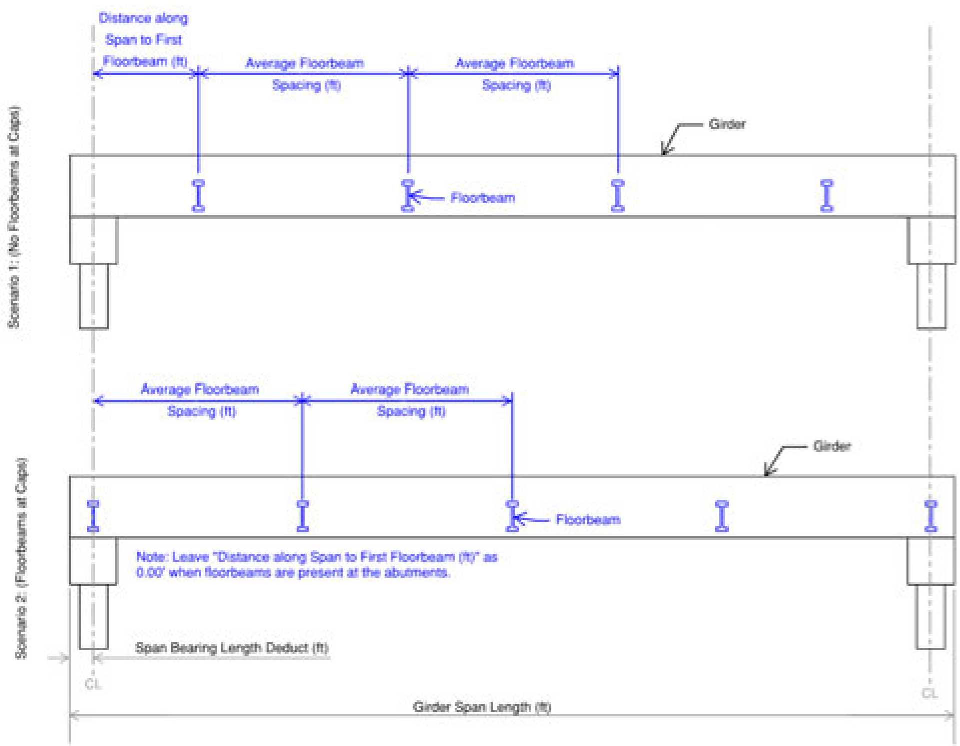
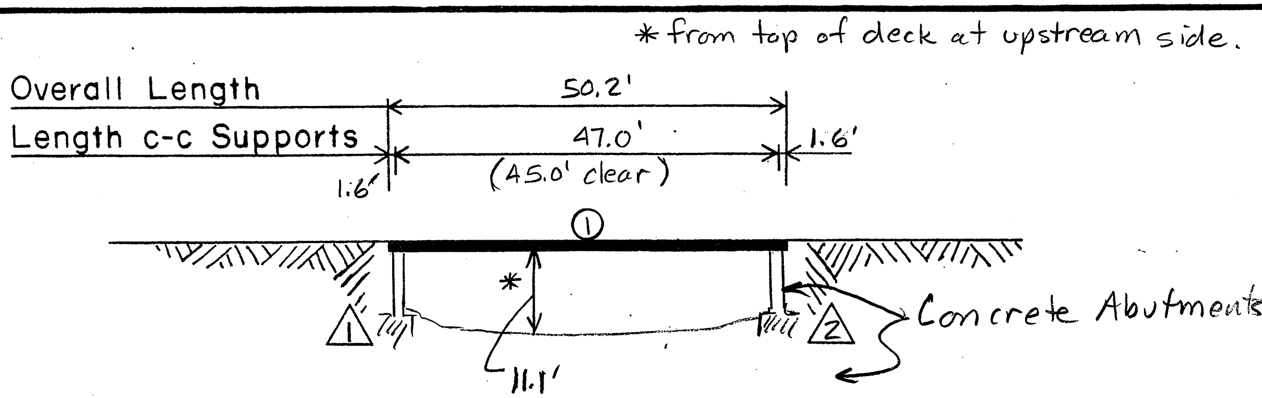


Figure 12: Floorbeam Layout and Spacing

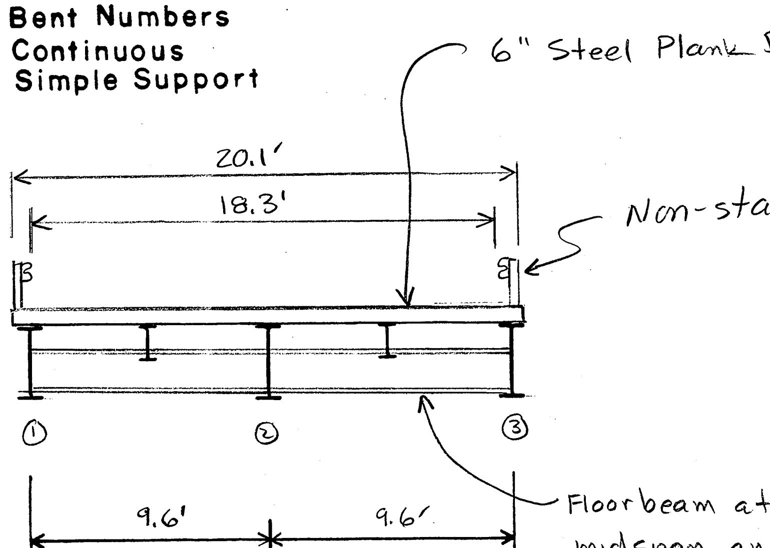
7. **Analysis**
   a. **Girder Capacity**
      i. See the flowchart in *Appendix C* for determining controlling moment capacities of non-hybrid, unstiffened, steel I-beams and plate girders according to the provisions of *AASHTO 10.48* through *10.50*.
         1. Per *AASHTO 10.48.3*, a transition (straight line interpolation) is allowed between *Eq. 10-92* and *Eq. 10-98* as long as the web thickness always satisfies *Eq. 10-94*.
   b. ***Dead Load Moments (M_{DL})***
      i. M_{DL} – All dead load moments are calculated as (1/8) * w_{DL} * L^2 at midspan.
      ii. M_{deck} – Includes Deck Weight and Misc. Loads inputs.
      iii. M_{beam} – Self weight of steel stringer and all cover plates calculated by the total cross-sectional area multiplied by 0.49 k/ft^3.
      iv. $M_{misc\ comp\ DL}$ – Includes Misc. Comp Dead Load per Beam input.
      v. $M_{misc\ non\text{-}comp\ DL}$ – Includes Misc. Non-Comp Dead Load per Beam input.
      vi. $M_{fill/wearing\ surface}$ – Includes Fill Weight and Wearing Surface Weight inputs.
      vii. $M_{floorbeam\ (Point\ Loads)}$ – Calculates the combined moment applied to the girder through each point load located at each floorbeam.
   c. ***Live Load Moments (M_{LL})***
      i. Distributed Live Load plus Impact moments per truck based on values from worksheets *LIVE LOADS*.
   d. Additional information on the analysis performed can be found to the right of the printed section.

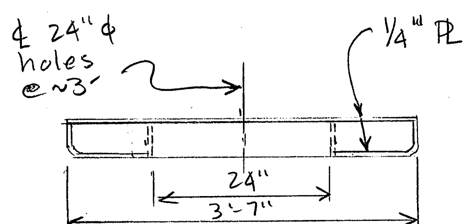
District 13 County 143 Cont.-Sec. AA01-47 Structure 001 Route CR 350



LEGEND
- ○ Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support

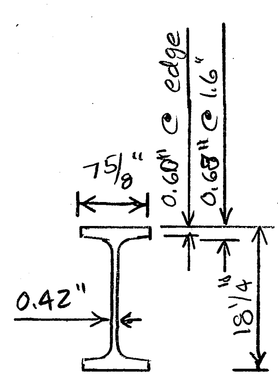
SIDE VIEW
(Looking SOUTH)





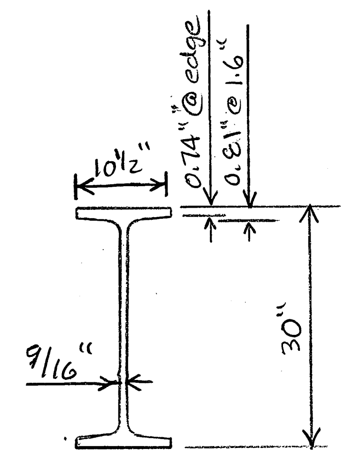
STEEL PLANK DECK

SPAN 1
(Looking West)



FLOORBEAMS AND INTERMEDIATE STRINGERS

WF 18 x 60 (S = 107.8 in^3)



STRINGERS ② & ③

WF 30 x 116 (S = 328 in^3)

STRINGER ① has 3/4" flanges with no slope. WF 30 x 108

SPAN

TBLRP-LFR Spreadsheet

Simple Span Steel Girder (GFS)

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Yoakum (13)	AADT ®:	50	# of Lanes:	1
County:	Lavaca (143)	Truck % (1% MIN):	1%		
Structure # :	AA01-47-001	EV Daily Crossing:	1	(1 or 10)	One Direction
Location:	CR 350 Over Boggy Creek	Year Built:	1995		
		Stringer Descr:	WF30x116 Interior Girder 2		

Girder Inputs

DATA INPUT TABLE	
Span ID:	1
Span Length (ft):	50.20
Span Bearing Length Deduct (ft):	3.20
F_y (ksi):	36.0
Girder Spacing (ft):	9.60
Misc. Comp Dead Load per Beam (k/ft):	0.000
Misc. Non-Comp Dead Load per Beam (k/ft):	0.000
Top Cover Plate Width (in):	0.000
Top Cover Plate Thickness (in):	0.000
Bottom Cover Plate Width (in):	0.000
Bottom Cover Plate Thickness (in):	0.000
Bottom Flange Unbraced Length, $L_{b\text{-}b}$ (ft):	47.00
Top Flange Unbraced Length, $L_{b\text{-}t}$ (ft):	0.00
DECK INPUTS	
Import Values from Defined Deck Module:	No Deck Import
Deck Type:	Steel Plate Deck
Deck Thickness (in):	6.000
Deck Weight (ksf):	0.031
Fill Weight (ksf):	0.000
Wearing Surface Weight (ksf):	0.000
Misc. Loads (ksf):	0.000
Girder Trib. Width for Deck Dead Loads (ft):	4.80

GIRDER PROPERTIES		
Standard Beam Designation:	30WF(B30),30X10.5x116	
Rolled Section Depth (in):	30.000	
Web Thickness (in):	0.564	
Flange Width (in):	10.500	
Top Flange Thickness (in):	0.850	
Bottom Flange Thickness (in):	0.850	
Compact Override (Y/N): Compact — Fillet Radius (in):	0.650	
Section Modulus (in^3):	328.62	
LIVE LOAD FACTORS		
Deck Type for LLDF:	Steel Plate	
Girder Location:	Interior	
	Calculated	Override
LLDF Calc = S /	5.5	
LL Moment Distribution Factor:	1.75	
EV_2 Operating LL Factor:	1.30	
EV_3 Operating LL Factor:	1.30	
Impact Factor (I):	1.29	
FLOORBEAM INPUTS		
Distance along Span to First Floorbeam (ft):	0.00	
Average Floorbeam Spacings (ft):	25.10	
Deck Dead Load (k):	3.7	
Stringers and Floorbeam Dead Load (k):	2.1	
Total Point Load to Girder per Floobeam (k):	5.8	
Number of Point Loads Applied along Girder:	1	

Analysis

Girder Capacity		
C_U =	1134.5	k-ft
C_{serv} =	788.7	k-ft

Dead Load Moments (M_{DL})	
$M_{DL} = (1/8) * w_{DL} * L^2$	k-ft
M_{deck} =	41.1
M_{beam} =	32.1
$M_{misc\ comp\ DL}$ =	0.0
$M_{misc\ non\text{-}comp\ DL}$ =	0.0
$M_{fill/wearing\ surface}$ =	0.0
$M_{floorbeam\ (Point\ Loads)}$ =	72.9
M_{DL} =	146.1

Live Load Moments (M_{LL})

Distributed Live Loads

	k-ft		k-ft
M_{LL} HS:	646.9	M_{LL} T3:	491.9
M_{LL} H:	468.2	M_{LL} T3S2:	446.1
M_{LL} SU_4:	565.7	M_{LL} T3-3:	412.1
M_{LL} SU_5:	612.3	M_{LL} NRL:	763.0
M_{LL} SU_6:	677.4	M_{LL} EV_2:	571.8
M_{LL} SU_7:	727.1	M_{LL} EV_3:	869.5

Additional Notes

Deck weight calculated to be 0.031 ksf.

€ - AASHTO 10.57 (Serviceability) Controls Ratings
¥ - Based on H-20 Rating
£ - AASHTO 10.57 (Serviceability) Controls Ratings

€ HS Ratings			
HS Inventory:	HS 11.9	RF= 0.60	
HS Operating:	HS 19.9	RF= 1.00	
¥£ H RATING			
H Inventory:	H 16.5	RF= 0.82	
H Operating:	H 27.5	RF= 1.38	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	1.14	TYPE 3:	1.30
SU_5 Operating:	1.05	TYPE 3S2:	1.44
SU_6 Operating:	0.95	TYPE 3-3:	1.56
SU_7 Operating:	0.89	NRL:	0.84
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.27	EV_3 Operating:	0.84

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Girder

Inputs

Span Length:	50.20	ft	Standard Beam Designation:	30WF(B30),30X10.5x116	
Span Bearing Length Deduct:	3.20	ft	Rolled Section Depth:	30.000	in
F_y:	36.0	ksi	Web Thickness:	0.564	in
Girder Spacing:	9.60	ft	Flange Width:	10.500	in
Misc. Comp Dead Load per Beam:	0.000	klf	Top Flange Thickness:	0.850	in
Misc. Non-Comp Dead Load per Beam:	0.000	klf	Bottom Flange Thickness:	0.850	in
Top Cover Plate Width:	0.000	in	Fillet Radius:	0.650	in
Top Cover Plate Thickness:	0.000	in	Section Modulus:	328.62	in^3
Bottom Cover Plate Width:	0.000	in	Deck Type for LLDF:	Steel Plate	
Bottom Cover Plate Thickness:	0.000	in	Girder Location:	Interior	
Deck Type:	Steel Plate Deck		LL Moment Distribution Factor:	1.75	
Deck Thickness:	6.000	in	EV2 Operating LL Factor:	1.30	
Deck Weight:	0.031	ksf	EV3 Operating LL Factor:	1.30	
Fill Weight:	0.000	ksf	Impact Factor (I):	1.29	
Wearing Surface Weight:	0.000	ksf	Distance along Span to First Floorbeam:	0.00	ft
Misc. Loads:	0.000	ksf	Average Floorbeam Spacing:	25.10	ft
Girder Trib. Width for Deck Dead Loads:	4.80	ft	Bot. Flange Unbraced Length:	47.00	ft
			Top Flange Unbraced Length:	0.00	ft

Capacity

C_u =	F_y*Z =	36.0 ksi * 378.2 in^3 * (1ft / 12 in) =	1134.5	ft-k
C_{serv} =	0.8*F_y*S_{xncmin} =	0.8 * 36.0 ksi * 328.6 in^3 * (1ft / 12 in) =	788.7	ft-k

Dead Loads

M_{deck} =	((0.149 klf) * (50.20 ft - 3.20 ft)^2) / 8 =	41.1	ft-k
M_{beam} =	((0.116 klf) * (50.20 ft - 3.20 ft)^2) / 8 =	32.1	ft-k
$M_{misc\ comp\ DL}$ =	(0.000 ksf * (50.20 ft - 3.20 ft)^2) / 8 =	0.0	ft-k
$M_{misc\ non\text{-}comp\ DL}$ =	(0.000 ksf * (50.20 ft - 3.20 ft)^2) / 8 =	0.0	ft-k
M_{fill} =	((0.000 ksf) * 2 ft * (50.20 ft - 3.20 ft)^2) / 8 =	0.0	ft-k
$M_{wearing\ surface}$ =	((0.000 ksf) * 2 ft * (50.20 ft - 3.20 ft)^2) / 8 =	0.0	ft-k
$M_{floorbeam}$ =	P_{FB} * a * x / L		
$M_{floorbeam}$ =	5.817 k * 25.10 ft * (25.10 ft / 50.20ft) =	73.0	ft-k
M_{DL} =	41.1 ft-k + 32.1 ft-k + 73.0 k-ft =	146.2	ft-k

Live Load Moments

From Live Load Moments Worksheet (Without Impact) =	287.2	ft-k
Distribution Factor (Single Lane) =	1.745	
HS Moment (one line of wheels) (Without Impact) =	501.3	ft-k

Rating Factors

Ultimate Capacity

HS-20 INV RF =	(1134.5 ft-k - 1.3 * 146.2 ft-k) / (2.17 * 501.3 ft-k * 1.29 (IM)) =	0.67	
		HS 13.5	
HS-20 OPR RF =	(1134.5 ft-k - 1.3 * 146.2 ft-k) / (1.3 * 501.3 ft-k * 1.29 (IM)) =	1.12	
		HS 22.5	

Serviceability

HS-20 INV RF =	(788.7 ft-k - 146.2 ft-k) / (5 * 501.3 ft-k * 1.29 (IM) / 3) =	0.60	
		HS 11.9	**<<<**
HS-20 OPR RF =	(788.7 ft-k - 146.2 ft-k) / (501.3 ft-k * 1.29 (IM)) =	1.00	
		HS 19.9	**<<<**

Note: Values above are rounded (not all decimals shown).

Section 14: Timber Stringer

1. **DATA INPUT TABLE**
    a. ***Span ID*** – The Span ID should correspond with the span numbers used on the bridge plans or inventory record.
    b. ***Span Type*** – Select Simple or Continuous from the Dropdown.
        i. ***Simple Span Length (ft)*** – If Simple Span is selected in the Span Type dropdown, input the length of the span here.
        ii. ***Controlling End Span (Cont.) Length (ft)*** – If Continuous is selected in the Span Type dropdown, input the controlling end span length here.
        iii. ***Controlling Int. Span (Cont.) Length (ft)*** – If Continuous is selected in the Span Type dropdown, input the controlling interior span length here. If there are no interior spans, this cell can be left blank.
    c. ***End Span or Int. Span*** – The user shall select if the span being evaluated is an end span or interior span. This input is used to calculate the Controlling Equivalent Simple Span Length in the MISC. STRINGER ANALYSIS PROPERTIES section.
    d. ***Stringer Spacing (in)*** – Input the spacing between stringers.
        i. Value should be centerline to centerline.
        ii. For closely spaced stringers, it is generally acceptable to use the average stringer spacing if the actual spacing varies slightly.
2. **DECK INPUTS**
    a. ***Import Values from Defined Deck Module*** – Select a deck module from the drop-down list to import previously input deck dead load info.
        i. Select 'No Deck Import' to define a new deck and input new dead loads.
    b. ***Deck Type*** – Select the Deck Type to use for the analysis.
        i. This is automatically filled in when values are imported.
    c. ***Deck Designation [Steel Corrugated Deck, Steel Open Grid Deck only]*** – Select the deck designation if Steel Corrugated Deck or Steel Open Grid Deck is selected above.
        i. If the corrugated deck that will be analyzed is not listed in the drop-down list, manually enter the decking scenario into this cell.
        ii. If the Steel Open Grid Deck that will be analyzed is not listed in the drop-down list, manually enter the decking scenario into this cell.
    d. ***Deck Thickness (in) [Concrete Deck, Steel Plate Deck, Timber Deck only]*** – Input the deck thickness if Concrete Deck, Steel Plate Deck, or Timber Deck is selected above.
        i. Deck weight below will automatically be calculated based upon the standard material unit weights of the selected Deck type.
    e. ***Deck Weight (ksf)*** – Value imported from deck module or calculated based on deck thickness input.
    f. ***Fill Weight (ksf)*** - Input the weight of fill acting on the member.
    g. ***Wearing Surface Weight (ksf)*** – Input the weight of wearing surface acting on the member.
    h. ***Misc. Loads (ksf)*** – Input any additional dead loads the user wishes to include in the analysis.

3. **STRINGER PROPERTIES**
    a. ***Stringer Height (in)*** – Input the height of the timber stringer.
    b. ***Notched Height (in)*** – Input the notched height of the timber stringer.
        i. The notched height should be left blank if no notches are present.
    c. ***Stringer Width (in)*** – Input the width of the timber stringer.
    d. ***Stringer Unit Weight (kcf)*** – Input the unit weight of the timber stringer.
        i. This value is typically around 0.050 kcf for timber.
    e. ***Allowable Bending Stress (Fb) (ksi)*** – Input a value for the allowable bending stress based upon the most recent bridge inspection performed.
        i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.
        ii. See *Figure 13: Allowable Bending Stress and Shear Stress values for Southern Pine (Stringers)* below.
    f. ***Allowable Shear Stress (Fv) (ksi)*** – Input a value for the allowable shear stress based upon the most recent bridge inspection performed.
        i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.
        ii. See *Figure 13: Allowable Bending Stress and Shear Stress values for Southern Pine (Stringers)* below.

	Protected		Unprotected	
Timber Grade or Condition	Bending	Shear	Bending	Shear
Clear Wood Lower Bound Strength	6.40	0.730	5.10	0.680
Clear Wood Allowable (Not Used)	3.00	0.180	2.45	0.170
Good Condition Structural 86 Allowable	2.60	0.155	2.10	0.145
Good Condition Structural 72 Allowable	2.20	0.130	1.75	0.120
Good Condition Structural 65 Allowable	2.00	0.115	1.60	0.110
Deteriorated Condition Fair			1.20	0.095
Deteriorated Condition Poor			0.80	0.085

Note: The recommended values above are for seasoned and pressure treated southern pine. Reduce these values by 25% for untreated timber. Stresses in the "Protected" column may be used if the stringers are above water in normal flow levels and if the deck prevents substantial saturation of the stringers due to rain.

Figure 13: Allowable Bending Stress and Shear Stress values for Southern Pine (Stringers)

    g. ***Misc. Dead Load (klf)*** – Input any additional dead loads the user wishes to include along the timber stringers.
        i. Examples of this could be attached utilities, attached railings to exterior stringers, attached diaphragms, etc.

4. **MISC. STRINGER ANALYSIS PROPERTIES**
   a. ***Deck Type for LLDF*** – Select the deck type to calculate the correct live load distribution factors (LLDF).
   b. ***LL Distribution Factor*** – The live load distribution factors are calculated based upon the following table:

Deck Type		1-Lane Bridge	2-Lane Bridge
TT, Treated Timber		s/4.00	s/3.75
UT, Untreated Timber		s/4.00	s/3.75
NL, Nail-Laminated Timber		s/4.50	s/4.00
CS, Corrugated Steel	< 2.0" thick	s/4.00	s/3.75
	≥ 2.0" thick	s/5.50	s/4.50
SG, Steel Grid		s/4.50	s/4.00
SP, Steel Plate		s/4.50	s/4.00
RC, Reinforced Concrete			
PC, Plain Concrete			
on steel beams		s/7.00	s/5.50
on timber beams		s/6.00	s/5.00

NOTES: s = Stringer Spacing (FT)

Distribution Factors are taken from table 3.23.1, Standard Specifications for Highway Bridges and are valid within the limits noted therein.

Refer to Table 3.23.1 to determine distribution factors for special cases not covered by the program.

Figure 14: Allowable Stress Wheel Load Distribution Factors for Stringers

   c. ***Effect. End Span Length (Continuous) (ft)*** – The value input for the Controlling End Span (Cont.) Length is converted into a simple span length within this cell (a 0.8 coefficient is used for End Spans)
      i. Formula = [Controlling End Span (Cont.) Length (ft)] x 0.8 (Eq. 14-1)
      ii. This cell is hidden when 'Simple' is selected for Span Type.
   d. ***Effect. Int. Span Length (Continuous) (ft)*** – The value input for the Controlling Int. Span (Cont.) Length is converted into a simple span length within this cell (a 0.7 coefficient is used for Int. Spans)
      i. Formula = [Controlling Int. Span (Cont.) Length (ft)] x 0.7 (Eq. 14-2)
      ii. This cell is hidden when 'Simple' is selected for Span Type.
   e. ***Controlling Equivalent Simple Span length (ft)*** – Based upon the values input and scenarios selected within the DATA INPUT TABLE section, this cell calculates the span length used within the analysis.
   f. ***Distance to Critical Section (ft)*** – This cell calculates the distance to the critical section for shear analysis. The critical section used for analysis is the minimum of the two calculated values:
      i. 3 x Stringer Height (feet)
      ii. Controlling Equivalent Simple Span Length (feet) / 4
   g. ***K*** – The K (Effective Height Factor) value is calculated based upon the stringer height and notched height. The formula for K is as follows:
      i. $(\text{Notched Height / Stringer Height})^2$
      ii. If no notch is present, K defaults to 1.0.

h. ***Effective Stringer Height (in)*** – The effective height is the Stringer Height multiplied by "K".

i. ***Sx (in^3)*** – The elastic section modulus for timber stringers is calculated as follows:

   i. (1/6) x Stringer Width (in) x [Effective Stringer Height (in)]^2

5. **Analysis**

   a. The Timber Stringer module uses allowable stress for its analysis, similar to the original TBLRP software.

   b. This module performs a bending analysis for positive moments and a shear analysis.

   c. Additional information and a further breakdown of this analysis and of the equations used can be found to the right of the printed section of the software and at the end of this section within the User Guide.

   d. The moment analysis for this module follows a similar logic to the original TBLRP. TBLRP-LFR calculates the maximum positive moments generated from live loads for H15 and HS15 trucks, along with the maximum positive moment from dead loads, and uses them to calculate the inventory and operating ratings based upon the calculated allowable moment of the timber stringer.

   e. The formulas used in the Moment Analysis section are explained below:

      i. **H15 Wheel Line Moment (k-ft)** is calculated based upon the scenarios outlined in *Figure 15*.

      ii. **HS15 Wheel Line Moment (k-ft)** is calculated based upon the scenarios outlined in *Figure 15*.

      iii. **M_{ALL} (k-ft)** = Allowable Bending Stress (Fb) (ksi) x S_x (in^3) x (1/12) (Eq. 14-3)

      iv. **M_{DL} (k-ft)** = Total Dead Load (klf) x Controlling Equivalent Simple Span Length (ft) x Controlling Equivalent Simple Span Length (ft) x (1/8) (Eq. 14-4)

      v. **[H15] - M_{LL} (k-ft)** = H15 Wheel Line Moment (k-ft) x LL Distribution Factor (Eq. 14-5)

      vi. **IR (H15)** = 15 x (M_{ALL} – M_{DL}) / M_{LL} (Eq. 14-6)

      vii. **IR (HS15)** = IR (H15) x H15 Wheel Line Moment (k-ft) / HS15 Wheel Line Moment (k-ft) (Eq. 14-7)

      viii. **OR (H15)** = 15 x ((1.36) x M_{ALL} – M_{DL}) / M_{LL} (Eq. 14-8)

      ix. **OR (HS15)** = OR (H15) x H15 Wheel Line Moment (k-ft) / HS15 Wheel Line Moment (k-ft) (Eq. 14-9)

f. The Shear analysis for this module follows a similar logic to the original TBLRP. TBLRP-LFR calculates the maximum shear generated from live loads for H15 and HS15 trucks, along with the maximum shear from dead loads, and uses them to calculate the inventory and operating ratings based upon the calculated allowable shear of the timber stringer.

g. The formulas used in the Shear Analysis section are explained below:

   i. ***H15 Wheel Line Shear (k)*** is calculated based upon the scenarios outlined in *Figure 16*.

   ii. ***HS15 Wheel Line Shear (k)*** is calculated based upon the scenarios outlined in *Figure 16*.

   iii. **V_{ALL} (k)** = (2/3) x Effective Height (in) x Stringer *Width (in) x Allowable Shear Stress (Fv) (ksi)* (Eq. 14-10)

   iv. **V_{DL} (k)** = [Controlling Equivalent Simple Span Length (ft) x (1/2) - Critical Section (ft)] x Total Dead Load (klf) (Eq. 14-11)

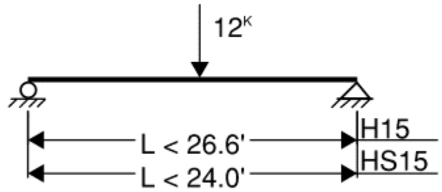
   v. **[H15] - V_{LL} (k)** = [(1/2) x ((3/5) +LL Distribution Factor) x H15 Wheel Line Shear] (Eq. 14-12)

   vi. **IR (H15)** = 15 x (V_{ALL} – V_{DL}) / V_{LL} (Eq. 14-13)

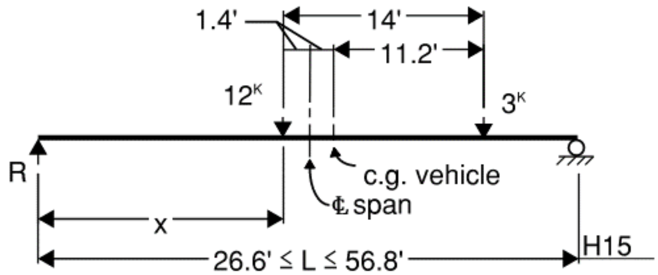
   vii. **IR (HS15)** = IR (H15) x H15 Wheel Line Shear (k) / HS15 Wheel Line Shear (k) (Eq. 14-14)

   viii. **OR (H15)** = 15 x ((1.36) x V_{ALL} – V_{DL}) / V_{LL} (Eq. 14-15)

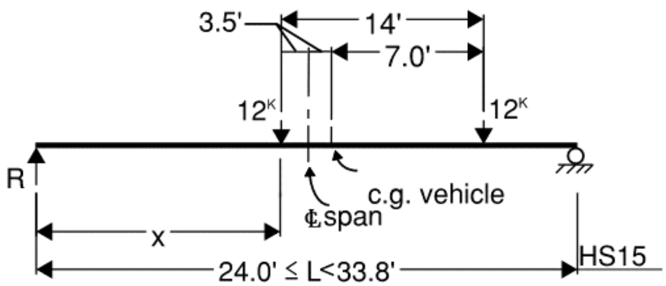
   ix. **OR (HS15)** = OR (H15) x H15 Wheel Line Shear (k) / HS15 Wheel Line Shear (k) (Eq. 14-16)



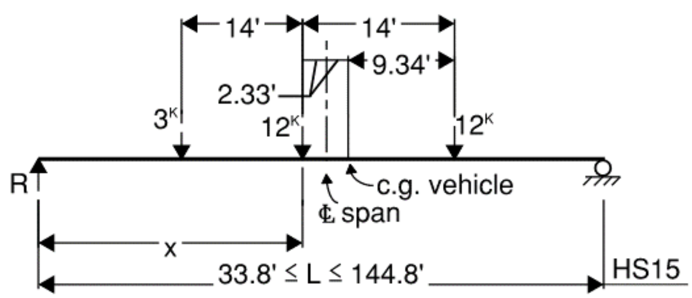
$$M_{WL} = \frac{P * L}{4} = 3.0 * L \qquad \text{(Eq. 14-17)}$$



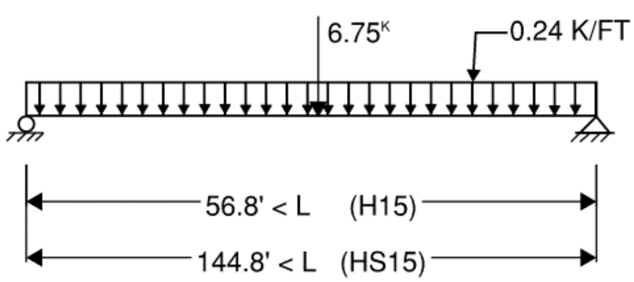
$$M_{WL} = R * X = 15 * \frac{L/2 - 1.4}{L} * (L/2-1.4)$$
$$= 15*(L/4 - 1.4 + 1.96/L) \qquad \text{(Eq. 14-18)}$$



$$M_{WL} = R * X = 24 * \frac{L/2 - 3.5}{L} * (L/2 - 3.5)$$
$$= 24 * (L/4 - 3.5 + 12.25/L) \qquad \text{(Eq. 14-19)}$$

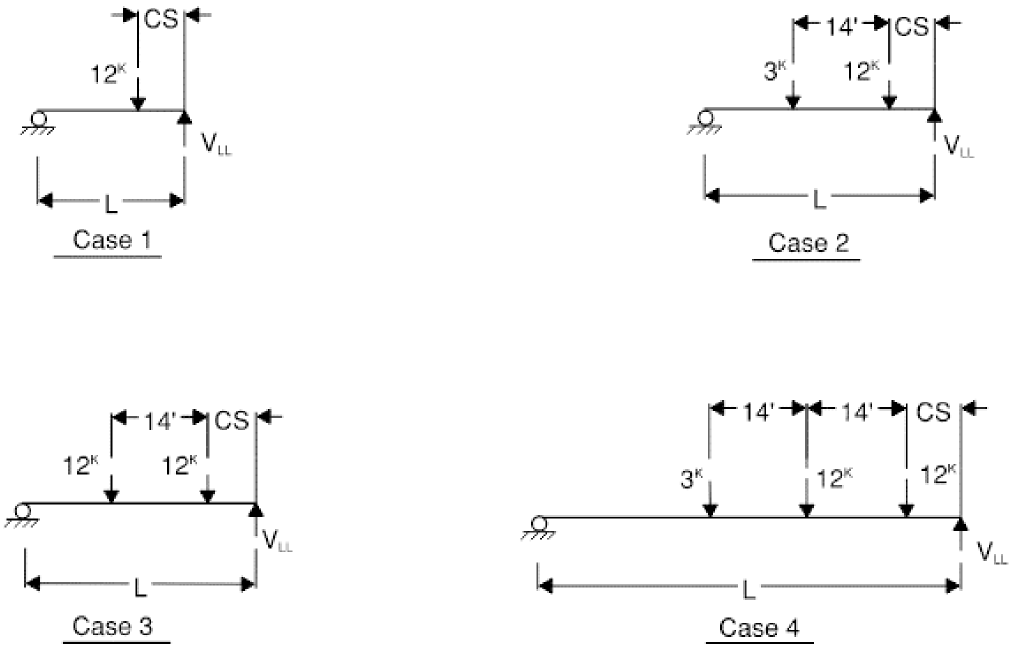


$$M_{WL} = 27 * \frac{L/2 - 2.33}{L} * (L/2 - 2.33) - 3 * 14$$
$$= 27 * (L/4 - 3.89 + 5.44/L) \qquad \text{(Eq. 14-20)}$$



$$M_{WL} = \frac{P * L}{4} + \frac{1}{8} * w * L^2$$
$$M_{WL} = \frac{6.75 * L}{4} + \frac{1}{8} * 0.24 * L^2$$
$$= 1.6875 * L + 0.03 * L^2 \qquad \text{(Eq. 14-21)}$$

Figure 15: H-15 and HS-15 Wheel Load Moments (Stringers)



LOAD CASE	RATING VEHICLE	SPAN LENGTH, L (FT)	WHEEL LINE SHEAR, VLL (KIPS)	
1	H15	L ≤ 14 + CS	VLL = 12 * (L - CS) / L	Eq. 14-22
2	H15	L > 14 + CS	VLL = 12 * (L - CS) / L + 3 * (L - 14.0 - CS) / L	Eq. 14-23
1	HS15	L ≤ 14 + CS	VLL = 12 * (L - CS) / L	Eq. 14-24
3	HS15	28 + CS ≥ L > 14 + CS	VLL = 24 * (L - 7 - CS) / L	Eq. 14-25
4	HS15	L > 28 + CS	VLL = 24 * (L - 7 - CS) / L + 3 * (L - 28 - CS) / L	Eq. 14-26

L = Stringer Span Length (FT)
CS = Distance to Critical Selection = 3 * Stringer Height ≤ L / 4 (FT)
VLL = Wheel Load Shear (KIPS)

Figure 16: H-15 and HS-15 Wheel Load Shear (Stringers)

TEXAS BRIDGE LOAD RATING PROGRAM

RATING EXAMPLE

CEDAR CREEK BRIDGE (Date Built: 1934)

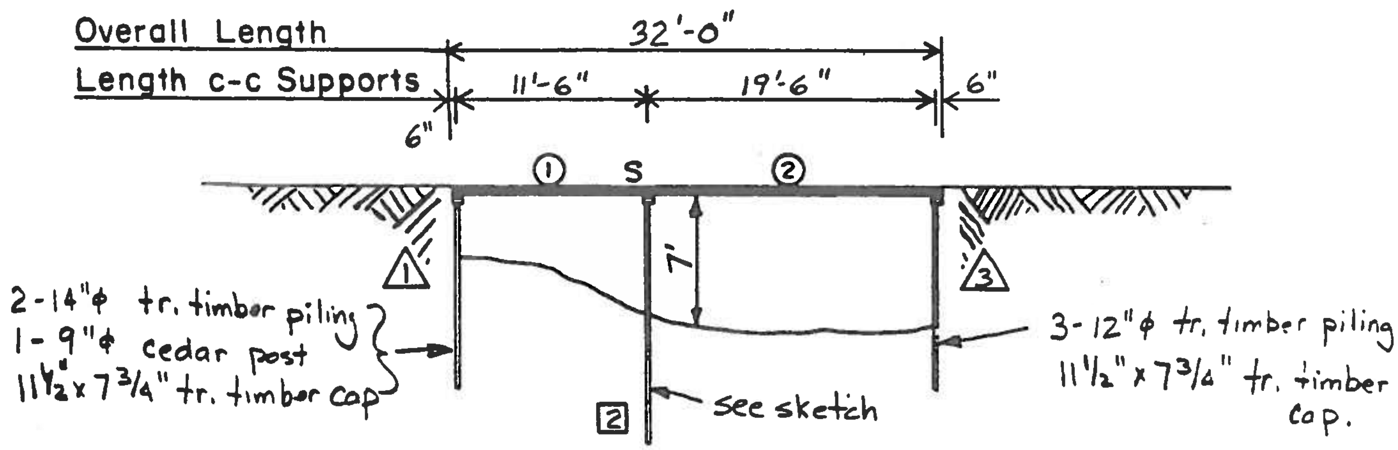
Bastrop County

I.D. No. AA0082-001

1-Lane Roadway

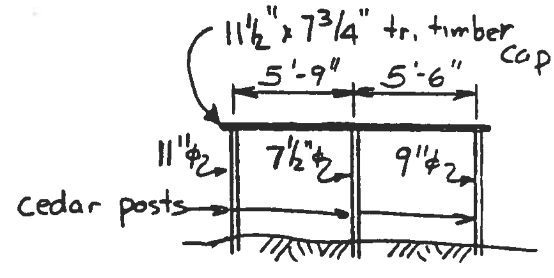
Posted Load Restriction: 8 TONS

Deck: Treated Southern Pine
2.75" x 8.5" Planks with
1.75" Timber Runners
Good Condition

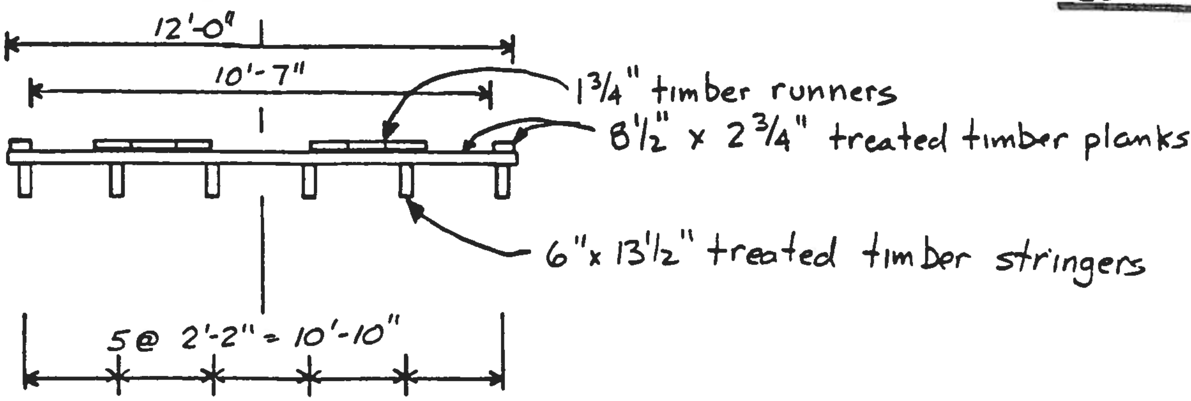


LEGEND
- ○ Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support

SIDE VIEW
(Looking South)



BENT 2



SPANS 1 & 2

TBLRP-LFR Spreadsheet

Timber Stringer (ASD)

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Austin (14)	AADT ®:	50	# of Lanes:	1
County:	Bastrop (011)	Truck % (1% MIN):	1%		
Structure # :	AA08-82-001	EV Daily Crossing:	1	(1 or 10) One Direction	
Location:	Roadway Over Cedar Creek	Year Built:	1934		
		Stringer Descr:	Interior 13.5" x 6.0" Timber Stringer		

Stringer Inputs

DATA INPUT TABLE	
Span ID:	Span 2 (West Span)
Span Type:	Simple
Simple Span Length (ft):	19.50
**Stringer Spacing (in):	26.000

***It is generally accepted to use the average springer spacing if the actual spacing varies.*

DECK INPUTS	
Import Values from Defined Deck Module:	Timber Deck
Deck Thickness (in):	2.750
Deck Weight (ksf):	0.011
Fill Weight (ksf):	0.000
Wearing Surface Weight (ksf):	0.007
Misc. Loads (ksf):	0.000

STRINGER PROPERTIES	
Stringer Height (in):	13.500
Notched Height (in):	
Stringer Width (in):	6.000
Stringer Unit Weight (kcf):	0.050
Allowable Bending Stress (F_b) (ksi):	1.600
Allowable Shear Stress (F_v) (ksi):	0.110
Misc. Dead Load (klf):	

MISC. STRINGER ANALYSIS PROPERTIES	
Deck Type for LLDF:	Treated Timber
LL Distribution Factor:	0.54
LL Impact	1.30
Controlling Equivalent Simple Span Length (ft):	19.50
Distance to Critical Section (ft):	3.38
K:	1.00
Effective Stringer Height (in):	13.500
S_x (in^3):	182.250

Analysis

Moment Analysis	
H15 Wheel Line Moment (k-ft):	58.5
HS15 Wheel Line Moment (k-ft):	58.5
M_{ALL} (k-ft):	24.3
M_{DL} (k-ft):	3.3
[H15] - M_{LL} (k-ft):	31.7
IR (H15):	10.0
IR (HS15):	10.0
OR (H15):	14.1
OR (HS15):	14.1

Shear Analysis	
H15 Wheel Line Shear (k):	10.3
HS15 Wheel Line Shear (k):	11.2
V_{ALL} (k):	5.9
V_{DL} (k):	0.4
[H15] - V_{LL} (k):	5.9
IR (H15):	14.1
IR (HS15):	12.9
OR (H15):	19.6
OR (HS15):	17.9

Additional Notes

Bridge condition and traffic values assumed.
Roadway unknown.

€ - Flexure Controls Rating
¥ - Based on H-20 Rating
£ - Flexure Controls Rating

€ HS Ratings			
HS Inventory:	HS 10.0	RF= 0.50	
HS Operating:	HS 14.1	RF= 0.70	
¥£ H RATING			
H Inventory:	H 10.0	RF= 0.50	
H Operating:	H 14.1	RF= 0.70	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	0.70	TYPE 3:	0.82
SU_5 Operating:	0.67	TYPE 3S2:	0.90
SU_6 Operating:	0.64	TYPE 3-3:	0.99
SU_7 Operating:	0.64	NRL:	0.64
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	0.67	EV_3 Operating:	0.45

Values calculated based on Allowable Stress Method

Timber Stringer

Inputs

Deck Unit Weight:	0.050	kcf	Span Type:	Simple	
Deck Thickness:	2.750	in	Simple Span Length:	19.50	ft
Wearing Surface (Runners) Unit Weight:	0.050	kcf	Stringer Height:	13.500	in
Wearing Surface (Runners) Thickness:	1.750	in	Notched Height (No Notch):	"left blank"	
Stringer Unit Weight:	0.050	kcf	Stringer Width:	6.000	in
Misc. Dead Load:	0	klf	Stringer Spacing:	26.000	in
Timber Stringer Condition:	*Good*		Allowable Bending Stress, $F_{b:}$	1.600	ksi
			Allowable Shear Stress, F_v:	0.110	ksi

Additional Properties Used in Analysis

LL Distribution Factor =	Stringer Spacing (ft)/ 4.00 ft = 26.000 in * (1 ft / 12 in) / 4.00 ft	=	0.54	
Controlling Equivalent Simple Span Length , L =	Simple Span Length	=	19.50	ft
K =	(Notched Height / Stringer Height)^2 = (13.500 in / 13.500 in)^2	=	1.000	
	Note: "K" is reduced when a member has a notch. When no notch is present, "K" = 1			
Effective Stringer Height =	(K) * Stringer Height	=	13.500	in

Dead Loads

Deck =	(2.750 in * (1 ft / 12 in)) * 0.050 kcf	=	0.011	ksf
Deck =	(0.011 k/ft^2) * (26.000 in * (1 ft / 12 in))	=	0.025	klf
Wearing Surface =	(1.750 in * (1 ft / 12 in)) * 0.050 kcf	=	0.007	ksf
Wearing Surface =	(0.007 k/ft^2) * (26.000 in * (1 ft / 12 in))	=	0.016	klf
Beam =	13.500 in * 6 in * (1 ft^2 / 144 in^2) * 0.050 kcf	=	0.028	klf
Misc. DL =			0.000	klf
Total Dead Load =			0.069	klf

Moment Analysis

Equation 16a: H15 Wheel Line Moment (k-ft) =	3 (k) * L (ft)			
H15 Wheel Line Moment (k-ft) =	3 (k) * 19.50 ft	=	58.5	k-ft
Equation 16a: HS15 Wheel Line Moment (k-ft) =	3 (k) * L (ft)			
HS15 Wheel Line Moment (k-ft) =	3 (k) * 19.50 ft	=	58.5	k-ft
M_{LL} =	LL Distribution Factor * H15 Wheel Line Moment (k-ft) = (0.54) * 58.5 k-ft	=	31.7	k-ft
M_{DL} =	(1/8) * Total Dead Load (k/ft) * L (ft)^2 = (1/8) * 0.069 k/ft * 19.50 ft * 19.50 ft	=	3.3	k-ft
S_x (in^3) =	(1/6) * Stringer Width * (Eff. Stringer Height)^2 = (1/6) * 6.000 in * 13.500 in * 13.500 in	=	182.250	in^3
M_{ALL} =	F_b * S_x = 1.600 ksi * 182.250 in^3 * (1 ft / 12 in)	=	24.3	k-ft
Inventory H Rating =	15 * (24.3 k-ft - 3.3 k-ft) / (31.7 k-ft)	=	**H 10.0**	<<<
Operating H Rating =	15 * ((1.36) * 24.3 k-ft - 3.3 k-ft) / (31.7 k-ft)	=	**H 14.1**	<<<
Inventory HS Rating =	H 10.0 * (58.5 k-ft) / (58.5 k-ft)	=	**HS 10.0**	<<<
Operating HS Rating =	H 14.1 * (58.5 k-ft) / (58.5 k-ft)	=	**HS 14.1**	<<<

Shear Analysis

	Distance to Critical Section, CS Check:			
	3 * Eff. Height (in) ≤ Controlling Equivalent Simple Span Length (ft) / 4			
	3 * 13.500 (in) / 12 in * 1 ft ≤ 19.50 (ft) / 4			
	3.38 ft ≤ 4.88 ft, OK			
	Distance to Critical Section, CS	=	3.38	ft
Equation 27b: H15 Wheel Line Shear (k) =	12 k * [L (ft) - CS (ft)] / L (ft) + 3 k * [L (ft) -14 ft - CS (ft)] / L (ft)			
H15 Wheel Line Shear (k-ft) =	12 k * (19.50 ft -3.38 ft) / 19.50 ft + 3 k * (19.50 ft - 14 ft - 3.38 ft) / 19.50 ft	=	10.3	k
Equation 28b: HS15 Wheel Line Shear (k) =	24 * [L (ft) -7 ft - Critical Section (ft)] / L (ft)			
HS15 Wheel Line Shear (k-ft) =	24 k * (19.50 ft - 7 ft - 3.38 ft) / 19.50 ft	=	11.2	k
V_{LL} =	[(1/2) * (0.6 + LL Distribution Factor)] * H15 Wheel Line Shear (k-ft)			
V_{LL} =	[(1/2) * (0.6 +0.54)] * 10.3 k	=	5.9	k
V_{DL} =	([Controlling Equivalent Simple Span Length (ft) / 2] - CS (ft)) * Total Dead Load (klf)			
V_{DL} =	([19.50 ft / 2] - 3.38 ft) * 0.069 k/ft	=	0.4	k
V_{ALL} =	(2/3) * Stringer Width (in) * Eff. Height (in) * Fv=(2/3) * 6.000 (in) * 13.500 (in) * 0.110 ksi	=	5.9	k
Inventory H Rating =	15 * (5.9 k - 0.4 k) / (5.9 k)	=	**H 14.1**	
Operating H Rating =	15 * (1.36 * 5.9 k - 0.4 k) / (5.9 k)	=	**H 19.6**	
Inventory HS Rating =	H 14.1 * (10.3 k-ft)/ (11.2 k-ft)	=	**HS 12.9**	
Operating HS Rating =	H 19.6 * (10.3 k) / (11.2 k)	=	**HS 17.9**	

Note: Values above are rounded (not all decimals shown).

Section 15: Steel Cap

1. **DATA INPUT TABLE**
   a. ***Bent ID Number*** - The Bent ID should correspond with the bent numbers used on the bridge plans or inventory record.
   b. ***Standard Beam Designation*** – Select a beam designation from the dropdown list.
      i. The dropdown list has been compiled from the AISC publication Iron and Steel Beams 1873 to 1972, otherwise known as *Historical Record, Dimensions and Properties, Rolled Shapes, Steel and Wrought Iron Beams & Columns, As Rolled in U.S.A., Period 1873 to 1972, With Sources as Noted*, compiled and edited by Herbert W. Ferris. The dropdown list also consists of the HP, S, and W-Shapes as provided by the AISC Shapes Database (V16.0).
      ii. The selected designation will populate the section dimensions below.
         1. Each section dimension can be overwritten to be the "remaining section" if section loss is present at the Engineer's discretion.
      iii. A new cap designation can be created by inputting all of the section dimensions.
         1. ***Rolled Section Depth (in)*** – Input the rolled section depth of the cap.
         2. ***Web Thickness (in)*** – Input the cap web thickness.
         3. ***Flange Width (in) –*** Input the cap flange width.
         4. ***Top Flange Thickness (in) –*** Input the cap top flange thickness.
         5. ***Bottom Flange Thickness (in) –*** Input the cap bottom flange thickness.
         6. ***Fillet Radius (in) –*** Input the fillet radius of the cap.
   c. ***Moment of Inertia (in^4)*** – Calculated from the section dimensions but can be overwritten.
      i. For a non-typical shape input the moment of inertia calculated from the section dimensions of the non-typical shape.
   d. ***Section Modulus, S (in^3)*** – Calculated from the section dimensions, but can be overwritten.
      i. For a non-typical shape, input the moment of inertia calculated from the section dimensions of the non-typical shape.
   e. ***Plastic Section Modulus, Z (in^3)*** – Calculated from the section dimensions, but can be overwritten.
      i. For a non-typical shape, input the plastic section modulus calculated from the section dimensions of the non-typical shape.
   f. ***F_y (ksi)*** – Input the yield stress of the steel cap. If unknown, this value is recommended based upon the date built, as seen in *Appendix A*.
   g. ***Cap Length (ft)*** – Input the cap length.
   h. ***Cap Weight (klf)*** – Calculated from the section dimensions, but can be overwritten.
   i. ***Cap Elastic Modulus (ksi)*** – Input the elastic modulus of the steel cap.
   j. ***Web Stiffeners Present (Y/N)*** – Select whether the web is considered adequately stiffened for additional shear capacity.

k. ***Abutment or Int. Bent*** – Select whether the steel cap is located at an abutment or interior bent.
l. ***Adjacent span Length 1 (ft) –*** Input the first adjacent span length.
m. ***Adjacent span Length 2 (ft) [Int. Bent Only] –*** Input the second adjacent span length.

2. **DECK INPUTS**
    a. ***Deck Type*** – Select the deck type and input the following deck inputs.
        i. If a deck module is available to import, it will import the Deck Thickness and Deck+Fill+Wear. Surface.
        ii. To input a concrete slab superstructure (i.e., flat slabs), select 'Concrete Slab' and input as the deck. The superstructure inputs will then be uneditable.
    b. ***Deck Thickness (in)*** – Input the deck thickness.
    c. ***Deck Elastic Modulus, E (ksi)*** – Input the elastic modulus of the deck.
    d. ***Deck+Fill+Wear. Surface (ksf)*** – Enter the total deck weight including deck, fill, wearing surface and miscellaneous loads.
        i. Dead loads from defined deck modules can be found in the table to the right of the printed section.
    e. ***Deck Width (ft)*** – Input the deck width.
3. **SUPERSTRUCTURE INPUTS**
    a. ***Superstructure Type*** – Select the superstructure type and input the following superstructure inputs.
        i. If a superstructure module is available to import, it will import the Stringer Weight and Stringer Spacing.
    b. ***Stringer Weight (klf)*** – Enter the stringer weight with all miscellaneous loads.
        i. Stringer weights from defined superstructure modules can be found in the table to the right.
    c. ***Number of Stringers*** – Enter number of stringers bearing on the cap.
    d. ***Distance to First Stringer from Edge of Deck (ft)*** – Enter the distance from the edge of deck to the first stringer (i.e. the deck overhang).
    e. ***Stringer Spacing (in)*** – Enter average stringer spacing on the cap.
        i. Stringer spacing from defined superstructure modules can be found in the table to the right.
4. **PILE INPUTS**
    a. ***Number of Piles*** – Input number of piles the cap is bearing on. The Pile Spacing Input Table to the right of the print area (shown to the right) will update with the number of bays. Input each pile bay spacing. (*Figure 17: Pile Spacing Input*)
    b. ***Distance to First Pile from Edge of Cap (ft)*** – Enter distance from edge of cap to centerline of the first pile.
        i. The software assumes the centerline of the cap and deck are at the same location.
    c. ***Pile Spacing (ft)*** – Each pile spacing must be input in the table to the right.

Pile Spacing Input	
Bay 1	5.00
Bay 2	
Bay 3	
Bay 4	
Bay 5	
Bay 6	
Bay 7	
Bay 8	
Bay 9	
Bay 10	
Bay 11	
Bay 12	
Bay 13	
Bay 14	
Bay 15	

Figure 17: Pile Spacing Input

5. **RUN CAP ANALYSIS**
    a. Push the ‘Run Cap Analysis’ button when all information in Data Input Table, Deck Inputs, Superstructure Inputs, and Pile Inputs have been input. Validation checks will run to ensure data was input correctly and a message box will notify the user of critical errors.
    b. Select "Yes" from the dropdown to print additional information regarding the reactions, shear, and moments generated in the Cap Analysis.
        i. This must be selected prior to selecting "Run Cap Analysis".
        ii. If left blank or "No" is selected, the detailed print table at Cell O200 will remain blank when analysis is run.
6. **ANALYSIS**
    a. ***Dead and Live Load Analysis***
        i. TBLRP-LFR estimates the live load shear and moments for continuous systems by using influence lines. The influence lines are calculated using Muller-Breslau's principle, see *Appendix F*. Each element in the continuous system is divided in ten (10) segments. Once the element is segmented, an influence line for each section at the end of each segment is calculated, ten (10) per segment. For example, a three-span continuous system will have a total of 30 segments and 29 sections. The sections at the exterior supports are not considered. Also, the shared section between elements is considered only once. In this example, 29 influence lines will be computed.
        TBLRP-LFR includes twelve standard trucks, H20, HS20, SHVs (4), EVs (2), T3, T3S2, T3-3, and NRL for estimating the live load shears and moments acting in the continuous span model. For each truck, the live load shear/moment at each section is estimated from its influence line by multiplying each truck axle’s weight times the corresponding influence line ordinate at the location of each truck axle as it moves along each span in the model. These values are tabulated and used to estimate the maximum live load shear and moment at each section. The load rating factors at each section are computed and the controlling factors are reported.
            1. Additional information on the analysis performed can be found to the right of the printed section.

b. ***Cap Capacity***

i. ***V_u*** (AASHTO 10.48.8)

1. For unstiffened webs, the shear capacity shall be limited to the plastic or buckling shear force (*AASHTO Eq. 10-113*)
2. For stiffened web panels complying with the provisions of *AASHTO 10.48.8.3*, the shear capacity shall be determined by (*AASHTO Eq. 10-114*)

ii. ***C_u***

1. See the flowchart in *Appendix C* for determining controlling moment capacities of non-hybrid, unstiffened, steel I-beams and plate girders according to the provisions of *AASHTO 10.48* through *10.50*.
    a. Per *AASHTO 10.48.3*, a transition (straight line interpolation) is allowed between *Eq. 10-92* and *Eq. 10-98* as long as the web thickness always satisfies *Eq. 10-94*.

iii. ***C_{serv}***

1. Calculated as $0.8 * F_y * S_x$

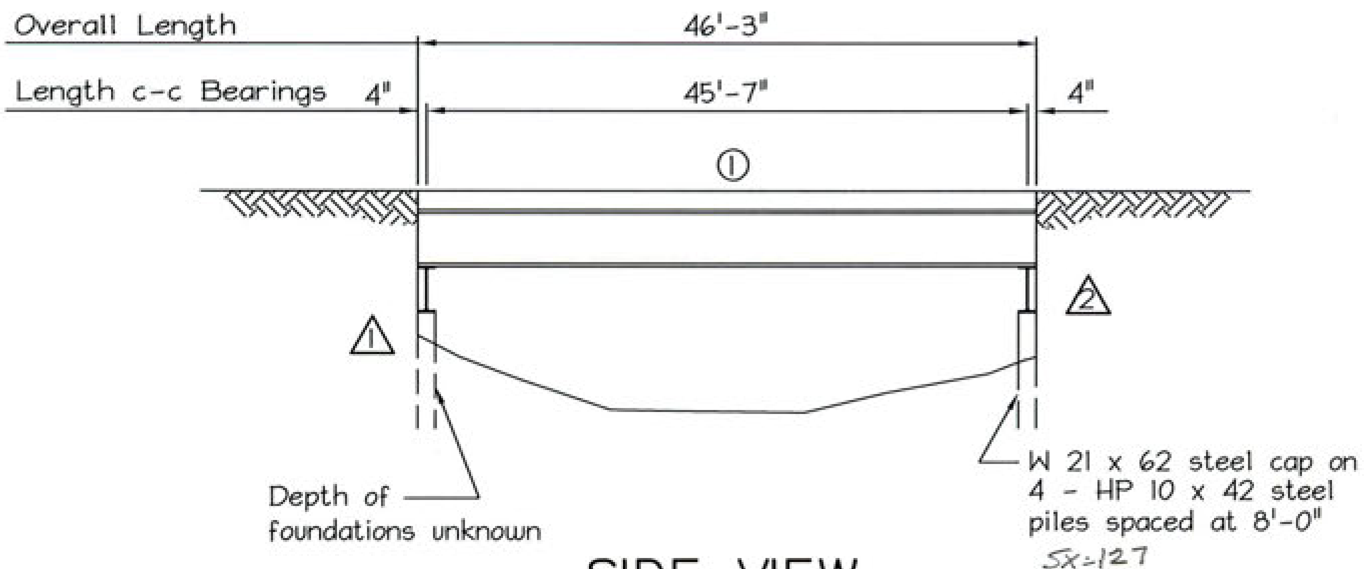
iv. ***Max [V, +M, -M] Dead and Live Load w/o IM***

1. The maximum [V, +M, -M] live loads are reported per truck as well as the corresponding span (pile bay) and dead load at that controlling section.

General Notes:

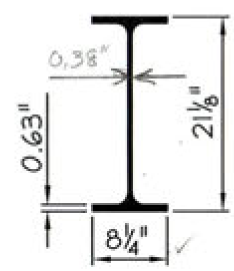
- Changing any of the inputs in the Data Input Table, Deck Inputs, Superstructure Inputs, or Pile Inputs tables will cause the analysis results to delete. The analysis will then need to re-run.
- Full Analysis results are shown in the table located at O116. Values are in k-in for moments and kips for shear.
- Rating factor calculations are shown in the table located at AL116 for the controlling section of each truck.
- A schematic is provided to the right for visual purposes only to assist the load rater in laying out the deck, superstructure, and piles in relation to the cap.
    - The visual is limited to a maximum of 25 stringers or slab strips.

District 13 County 143 Cont.–Sec. AA01-75 Structure 001 Route CR 280

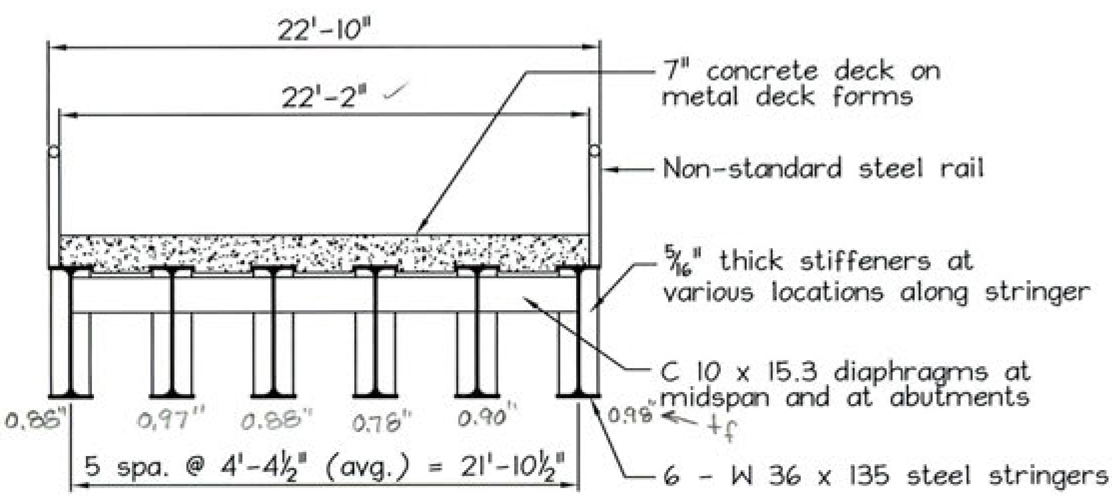


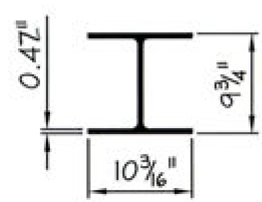
SIDE VIEW
(Looking West)

LEGEND
- O Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support

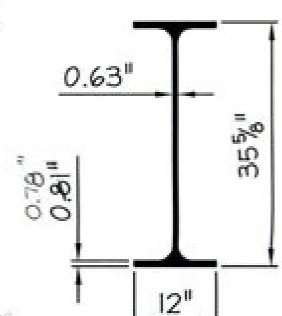


W 21 x 62
Steel cap





HP 10 x 42
Steel pile



SPAN 1
(Looking South)

Most are W36x150
W 36 x 135
Steel stringer
(Min. Dimensions Shown)

TBLRP-LFR Spreadsheet

Steel Cap

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Yoakum (13)	**AADT ®:**	50 **# of Lanes:** 1
County:	Lavaca (143)	**Truck % (1% MIN):**	1%
Structure # :	AA01-75-001	**EV Daily Crossing:**	1 **(1 or 10)** One Direction
Location:	CR 280 Over Ponton Creek	**Year Built:**	2005
		Cap Descr:	W21x62 Steel Cap at Bent 1

Cap Inputs

DATA INPUT TABLE	
Bent ID Number:	1
Standard Beam Designation:	W21X62
Rolled Section Depth (in):	21.000
Web Thickness (in):	0.400
Flange Width (in):	8.240
Top Flange Thickness (in):	0.615
Bottom Flange Thickness (in):	0.615
Fillet Radius (in):	0.530
Moment of Inertia (in4):	1333.808
Z (in3): 144.743 S (in3):	127.029
Fy (ksi):	36.0
Cap Length (ft):	25.00
Cap Weight (klf):	0.062
Cap Elastic Modulus (ksi):	29000.0
Web Stiffeners Present (Y/N):	N
Abutment or Int. Bent	Abutment
Adjacent Span Length 1 (ft):	46.25
Adjacent Span Length 2 (ft):	0.00

DECK INPUTS	
Deck Type:	Concrete Deck
Deck Thickness (in):	7.000
Deck Elastic Modulus, E (ksi):	3122.0
Deck+Fill+Wear. Surface (ksf):	0.088
Deck Width (ft):	22.83
SUPERSTRUCTURE INPUTS	
Superstructure Type:	Steel Stringer
Stringer Weight (klf):	0.135
Number of Stringers:	6
Distance to First Stringer from Edge of Deck (ft):	0.48
Stringer Spacing (in):	52.500
PILE INPUTS	
Number of Piles:	4
Distance to First Pile from Edge of Cap (ft):	0.50
Pile Spacing (ft):	8 - 8 - 8

Analysis

Cap Capacity		
V_U =	165.1	*k*
M_U =	434.2	*k-ft*
M_{serv} =	304.9	*k-ft*

Detailed Analysis Print: No

	Max +M Live Load w/o IM			***Max -M Live Load w/o IM***			***Max V Dead and Live Load w/o IM***		
Truck	Span	DL (k-ft)	LL (k-ft)	Span	DL (k-ft)	LL (k-ft)	Span	DL (k)	LL (k)
HS:	1	12.5	27.4	2	19.6	35.9	2	12.1	25.4
SU_4:	1	12.5	23.4	1	19.6	29.1	2	12.1	21.2
SU_5:	1	12.5	26.1	1	19.6	32.2	2	12.1	23.6
SU_6:	1	12.5	27.5	2	19.6	33.7	2	12.1	24.7
SU_7:	1	12.5	28.6	1	19.6	35.0	2	12.1	25.7
EV_2:	1	12.5	22.8	1	19.6	31.0	2	12.1	21.5
EV_3:	1	12.5	36.4	2	19.6	46.0	2	12.1	33.2
T3:	1	12.5	20.9	1	19.6	26.3	2	12.1	19.0
T3S2:	1	12.5	21.7	1	19.6	27.0	2	12.1	19.6
T3-3:	1	12.5	20.3	1	19.6	25.5	2	12.1	18.5
NRL:	1	12.5	28.5	1	19.6	34.9	2	12.1	25.6

Additional Notes

Cap length assumed to be 25'-0".

€ - Strength Controls Ratings
§ - Shear Controls Ratings
¥ - Based on H-20 Rating
£ - Strength Controls Ratings

€§ HS Ratings		
HS Inventory:	HS 41.7	RF= 2.09
HS Operating:	HS 69.6	RF= 3.48
¥£ H RATING		
H Inventory:	H 67.0	RF= 3.35
H Operating:	H 111.8	RF= 5.59

AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	4.17	**TYPE 3:**	4.65
SU_5 Operating:	3.75	**TYPE 3S2:**	4.50
SU_6 Operating:	3.58	**TYPE 3-3:**	4.79
SU_7 Operating:	3.44	**NRL:**	3.46
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	4.10	**EV_3 Operating:**	2.66

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Cap

Inputs

Standard Beam Designation:	W 21 x 62		Deck Type:	Concrete Deck	
Rolled Section Depth:	21.000	in	Deck Thickness:	7.000	in
Web Thickness:	0.400	in	Deck Elastic Modulus, E:	3122.0	ksi
Flange Width:	8.240	in	Deck+Fill+Wear. Surface:	0.088	ksf
Top Flange Thickness:	0.615	in	Deck Width:	22.83	ft
Bottom Flange Thickness:	0.615	in	SUPERSTRUCTURE INPUTS		
Fillet Radius:	0.530	in	Superstructure Type:	Steel Stringer	
Moment of Inertia:	1333.808	in^4	Stringer Weight:	0.135	klf
S:	127.029	in^3	Number of Stringers:	6	
Z:	144.743	in^3	Distance to First Stringer from Edge of Deck:	0.48	ft
F_y:	36.0	ksi	Stringer Spacing:	52.500	in
Cap Length:	25.00	ft	PILE INPUTS		
Cap Weight:	0.062	klf	Number of Piles:	4	
Cap Elastic Modulus:	29000.0	ksi	Distance to First Pile from Edge of Cap:	0.50	ft
Web Stiffeners Present (Y/N):	N		Pile Spacing:	8 - 8 - 8	ft
Abutment or Int. Bent:	Abutment				
Adjacent span Length 1:	46.25	ft			
Adjacent span Length 2:	0.00	ft			

Capacity

V_u =	$C*0.58*F_y*D*t_w$ =			165.1	k
M_u =	F_y*Z_x =	36.0 ksi * 144.743 in^3 * (1 ft / 12 in)	=	434.2	k-ft
M_{serv} =	$0.8*F_y*S_x$ =	0.8 * 36.0 ksi * 127.029 in^3 * (1 ft / 12 in)	=	304.9	k-ft

Analysis

TBLRP-LFR estimates the dead and live load shears/moments for continuous systems (stringers, caps, etc) by using influence lines. See Appendix B for more information.

	Span	DL	HS20	
Shear	1	**12.6**	**24.0**	**k**
Mom pos		150.5	328.5	k-in
		12.5	**27.4**	**k-ft**
Mom neg		235.2	431.3	k-in
		19.6	**35.9**	**k-ft**
Shear	2	**12.1**	**25.4**	**k**
Mom pos		26.0	261.6	k-in
		2.2	**21.8**	**k-ft**
Mom neg		235.2	431.3	k-in
		19.6	**35.9**	**k-ft**
Shear	3	**12.6**	**23.6**	**k**
Mom pos		150.9	303.6	k-in
		12.6	**25.3**	**k-ft**
Mom neg		235.2	426.6	k-in
		19.6	**35.6**	**k-ft**

Rating Factors

Controlling Rating Factors

Shear

HS-20 INV RF =	(165.119 k - 1.3 * 12.1 k-ft) / (2.17 * 25.4 k-ft * 1.3 (IM))	=	2.09	**HS 41.7**	**<<<**
HS-20 OPR RF =	(165.119 k - 1.3 * 12.1 k-ft) / (1.3 * 25.4 k-ft * 1.3 (IM))	=	3.48	**HS 69.6**	**<<<**

Positive Moment

HS-20 INV RF =	(434.2 k-ft - 1.3 * 150.5 k-ft * (1 ft / 12 in)) / (2.17 * 328.5 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	5.41	HS 108.2
HS-20 OPR RF =	(434.2 k-ft - 1.3 * 150.5 k-ft * (1 ft / 12 in)) / (1.3 * 328.5 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	9.03	HS 180.7
HS-20 INV RF_{SERV} =	(304.9 k-ft - 150.5 k-ft * (1 ft / 12 in)) / (5 / 3 * 328.5 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	4.93	**HS 98.6**
HS-20 OPR RF_{SERV} =	(304.9 k-ft - 150.5 k-ft * (1 ft / 12 in)) / (328.5 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	8.23	**HS 164.6**

Negative Moment

HS-20 INV RF =	(434.2 k-ft - 1.3 * 235.2 k-ft * (1 ft / 12 in)) / (2.17 * 431.3 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	4.03	HS 80.6
HS-20 OPR RF =	(434.2 k-ft - 1.3 * 235.2 k-ft * (1 ft / 12 in)) / (1.3 * 431.3 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	6.73	HS 134.6
HS-20 INV RF_{SERV} =	(304.9 k-ft - 235.2 k-ft * (1 ft / 12 in)) / (5 / 3 * 431.3 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	3.66	**HS 73.3**
HS-20 OPR RF_{SERV} =	(304.9 k-ft - 235.2 k-ft * (1 ft / 12 in)) / (431.3 k-ft * (1 ft / 12 in)) * 1.3 (IM))	=	6.12	**HS 122.4**

Note: Values above are rounded (not all decimals shown).

Section 16: Timber Cap

1. **DATA INPUT TABLE**
    a. ***Bent ID Number*** – The Bent ID should correspond with the bent ID numbers used on the bridge plans or inventory record.
    b. ***Pile Spacing (ft)*** – Input the spacing between piles for the section of cap being analyzed.
        i. The distance between piles should be centerline to centerline.
    c. ***Equivalent Length Factor*** – Input 1.0 if there are only two piles. If 3 or more piles are present, and the cap is continuous over these piles, 0.8 can be used per the engineer's discretion.
    d. ***Cap Unit weight (kcf)*** – Input the unit weight of the timber cap.
        i. This value is typically around 0.050 kcf for timber.
    e. ***Cap Width (in)*** – Input the width of the timber cap.
    f. ***Cap Height (in)*** – Input the height of the timber cap.
    g. ***Notched Height (in)*** – Input the notched height of the timber cap.
        i. The notched height should be left blank if no notches are present.
    h. ***Cap Condition*** – Select the general condition of the cap being analyzed.
        i. The Cap Condition is referenced by the Allowable Bending Stress and Allowable Shear Stress cells within the MISC. CAP ANALYSIS PROPERTIES section.
        ii. This condition should be based upon the most recent inspection.
        iii. See *Figure 18*: Allowable Bending Stress and Shear Stress for Southern Pine (Caps).
    i. ***Abutment or Int. Bent*** – Select whether the timber cap is located at an abutment or at an intermediate bent.
    j. ***Adjacent Span Length 1 (ft)*** – Input the adjacent span length for an abutment cap or intermediate bent cap.
    k. ***Adjacent Span Length 2 (ft)*** – Input the other adjacent span length for an intermediate bent cap.
        i. This cell turns to 0.00 ft if 'Abutment' is selected above.
    l. ***Superstructure Material Type*** – Select the material type of the superstructure member(s) transferring their forces to the cap being analyzed.
        i. This input is utilized when considering the effect of negative moments over the cap if the superstructure is defined as "Continuous" below.
    m. ***Is Superstructure Continuous Over Cap*** – Select from the drop-down list whether the superstructure is continuous over the cap.
2. **DEAD LOAD CALCS**

    Note: The tables to the right of the printed section can be referenced if deck and superstructure modules have been previously filled out. Please review and verify these values prior to copying them into the cells within this section.

    a. ***Effective Deck Length for Dead Loads (ft)*** – The value in this cell is auto-calculated based upon the adjacent span length inputs in the DATA INPUT TABLE.
        i. This cell shows the total span being resisted by the cap in question.
        ii. For abutment caps, this is half of the Adjacent Span Length 1 value.

    iii. For intermediate bents, this is half of the Adjacent Span Length 1 value plus half of the Adjacent Span Length 2 value.

  b. ***Deck Type*** – Select the deck type from the drop-down list.
    i. To input a concrete slab superstructure (i.e. flat slabs), select 'Concrete Slab' and input dead load values below.
    ii. When 'Concrete Slab' is selected, the superstructure inputs for dead loads will become un-editable.
  c. ***Deck+Fill+Wear. Surface (ksf)*** – Enter the total deck weight including fill, wearing surface, and any other miscellaneous loads.
  d. ***Superstructure Type*** – Select the superstructure type and input the following superstructure inputs.
  e. ***Superstructure Member Spacing (in)*** – Enter the average stringer spacing on the cap.
    i. Values for this cell should be input from centerline to centerline of superstructure members when possible.
  f. ***Superstructure Member Weight (klf)*** – Enter the average superstructure member weight in the longitudinal orientation for the section of timber cap being analyzed.
  g. ***Cap Weight (klf)*** – This cell is auto-calculated based upon the Cap Width, Cap Height, and Cap Unit Weight values input within the DATA INPUT TABLE.
    i. This weight is calculated in the transverse orientation.
  h. ***Total Dead Load (klf)*** – This cell auto-calculates the total dead load along the length of the cap (transverse orientation).
    i. This cell converts the deck and superstructure weights to klf along the length of the cap using the Effective Deck Length for Dead Loads value above.

3. **MISC. CAP ANALYSIS PROPERTIES**
  a. ***Equiv. Simple Span Length (ft)*** – This length is the converted length of cap resisting forces based upon the Equivalent Length Factor value.
  b. ***K*** – The K (Effective Height Factor) value is calculated based upon the cap height and notched height. The formula for 'K' is as follows:
    i. $(\text{Notched Height} / \text{Cap Height})^2$
    ii. If no notch is present, 'K' defaults to 1.0.
  c. ***Effective Cap Height (in)*** – The effective height is the Cap Height (in) multiplied by 'K'.
  d. ***Allowable Bending Stress (Fb) (ksi)*** – Input a value for the allowable bending stress based upon the most recent bridge inspection performed.
    i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.
    ii. See *Figure 18*.
  e. ***Allowable Shear Stress (Fv) (ksi)*** – Input a value for the allowable shear stress based upon the most recent bridge inspection performed.
    i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.
    ii. See *Figure 18.*

Timber Condition	Bending	Shear
Good (Minor decay and weathering)	1.60	0.165
Fair (Substantial decay or damage)	1.20	0.125
Poor (Severe deterioration)	0.80	0.080

Note: The values for shear include a 50% increase permitted by Article 3.4.4.2 (c) of the National Design Specification for Wood Construction, 1982 Edition.

Figure 18: Allowable Bending Stress and Shear Stress for Southern Pine (Caps)

f. **Sx (in^3)** – The section modulus for the timber cap is calculated as follows:
   i. (1/6) x (Cap Width (in)) x (Effective Cap Height (in))^2
   ii. This calculated value will be used to calculate the timber cap's Allowable Bending Moment within the Analysis section below.
g. ***Distance to Critical Section (ft)*** – This cell calculates the distance to the critical section for shear analysis. The critical section used for analysis calculated as follows:

$$\text{Distance to Critical Section (ft)} = \frac{[\text{Pile Spacing (ft)} / 4] + [3 \times \text{Cap Height (ft)}]}{2}$$

(Eq. 16-1)

h. ***Effective Horizontal Shear Factor, K_S*** – This cell calculates the Effective Horizontal Shear Factor based upon the following equation:

$$K_S = (10/9) \times \frac{\left(\frac{[\text{Distance to Critical Section (ft)}]}{[\text{Cap Height (ft)}]}\right)^2}{2 + \left(\frac{[\text{Distance to Critical Section (ft)}]}{[\text{Cap Height (ft)}]}\right)^2} \leq 1.0$$

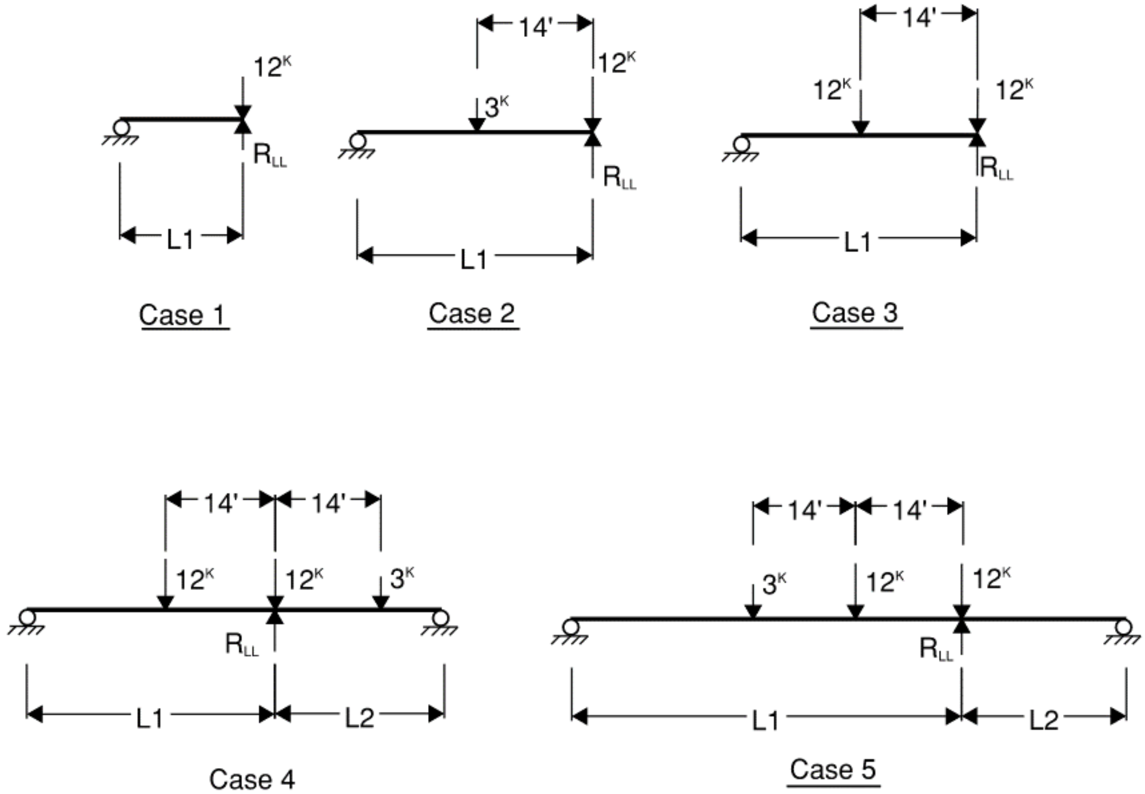
(Eq. 16-2)

4. **Analysis**
   a. The Timber Cap module uses allowable stress for its analysis, similar to the Original TBLRP software.
   b. This module performs a bending analysis for positive moments and a shear analysis.
   c. TBLRP-LFR does not account for lane loading analysis for the Timber Cap. If lane loading is warranted for a specific structure, please load rate the Timber Cap using another method of analysis.
   d. Additional information and a further breakdown of this analysis and of the equations used can be found to the right of the printed section of the software and at the end of this section within the User Guide.
   e. The moment analysis for this module follows a similar logic to the original TBLRP. TBLRP-LFR calculates the maximum positive moments generated from live loads for the H-15 and HS-15 Trucks, along with the maximum positive moment from dead loads, and uses them to calculate the inventory and operating ratings based upon the calculated allowable moment of the timber cap.

f. The formulas used in the Moment Analysis section are explained below:
    i. **Max H15 Reaction (k)** is calculated based upon the scenarios outlined in *Figure 19*.
    ii. **Max HS15 Reaction (k)** is calculated based upon the scenarios outlined in *Figure 19.*
    iii. **M_{ALL} (k-ft)** = Allowable Bending Stress (Fb) (ksi) x Sx (in^3) x (1/12) (Eq. 16-3)
    iv. **M_{DL} (k-ft)** = Total Dead Load (klf) x Controlling Equivalent Simple Span Length (ft) x Controlling Equivalent Simple Span Length (ft) x (1/8) (Eq. 16-4)
    v. **[Max H15] - M_{LL} (k-ft)** is calculated based upon the scenarios outlined in *Figure 20.*
    vi. **IR (H15)** = 15 x (M_{ALL} – M_{DL}) / M_{LL} (Eq. 16-5)
    vii. **IR (HS15)** = IR (H15) x Max H15 Reaction (k) / Max HS15 Reaction (k) (Eq. 16-6)
    viii. **OR (H15)** = 15 x ((1.36) x M_{ALL} – M_{DL}) / M_{LL} (Eq. 16-7)
    ix. **OR (HS15)** = OR (H15) x Max H15 Reaction (k) / Max HS15 Reaction (k) (Eq. 16-8)

g. The Shear analysis for this module follows a similar logic to the original TBLRP. TBLRP-LFR calculates the maximum shear generated from live loads for H15 and HS15 trucks, along with the maximum shear from dead loads, and uses them to calculate the inventory and operating ratings based upon the calculated allowable shear of the Timber Cap.

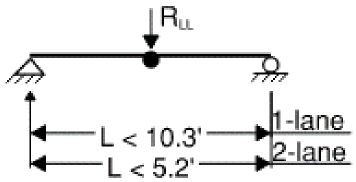
h. The formulas used in the Shear Analysis section are explained below:
    i. **Max H15 Reaction (k)** is calculated based upon the scenarios outlined in *Figure 19.*
        1. This reaction value is compared against the reaction generated from lane loading, with the controlling reaction being used.
    ii. **Max HS15 Reaction (k)** is calculated based upon the scenarios outlined in *Figure 19.*
        1. This reaction value is compared against the reaction generated from lane loading, with the controlling reaction being used.
    iii. **V_{ALL} (k)** = (2/3) x Effective Height x Cap Width x Allowable Shear Stress (F_v) (Eq. 16-9)
    iv. **V_{DL} (k)** = [Pile Spacing x (1/2) – Cap Height x (1/12)] x Total Dead Load (Eq. 16-10)
    v. **[Max H15] - V_{LL} (k)** is calculated based upon the scenarios outlined in *Figure 21*.
    vi. **IR (H15)** = 15 x (V_{ALL} – V_{DL}) / V_{LL} (Eq. 16-11)
    vii. **IR (HS15)** = IR (H15) x Max H15 Reaction (k) / Max HS15 Reaction (k) (Eq. 16-12)
    viii. **OR (H15)** = 15 x ((1.36) x V_{ALL} – V_{DL}) / V_{LL} (Eq. 16-13)
    ix. **OR (HS15)** = OR (H15) x Max H15 Reaction (k) / Max HS15 Reaction (k) (Eq. 16-14)



Load Case	Rating Vehicle	L1(FT)	L2(FT)	WHEEL LINE REACTION, R_{LL} (K)	
1	H15	L1 ≤ 14	L2 ≤ L1	RLL = 12	Eq. 16-15
2	H15	L1 > 14	L2 ≤ L1	RLL = 12 + 3.0 (L1 - 14.0) / L1	Eq. 16-16
1	HS15	L1 ≤ 14	L2 ≤ L1	RLL = 12	Eq. 16-17
3	HS15	28 ≥ L1 > 14	L2 ≤ 14	RLL = 12*(2*L1-14) / L1	Eq. 16-18
4	HS15	28 ≥ L1 > 14	L1 ≥ L2 >14	RLL = 12*(2*L1-14) / L1+3 (L2-14) / L2	Eq. 16-19
5	HS15	L1 > 28	L2 ≤ L1 / 2	RLL = 12*(2*L1-14) / L1+3 (L1-28) / L1	Eq. 16-20
4	HS15	L1 > 28	L2 > L1 / 2	RLL = 12*(2*L1-14) / L1+3 (L2-14) / L2	Eq. 16-21

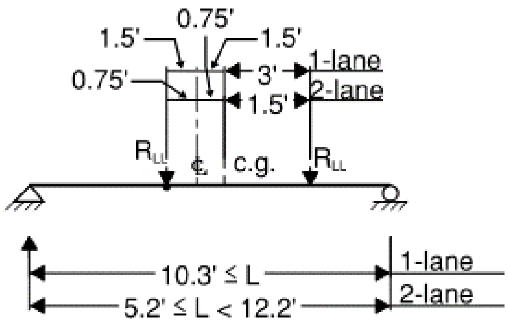
L1 = Larger Distance between adjacent caps (FT)
L2 = Smaller Distance between adjacent caps (FT)
R_{LL} = Wheel Load Reaction (K)

Figure 19: Wheel Load Reactions on Caps (Timber)



1 WHEEL LINE

$$M_{LL} = R_{LL} * L / 4 \text{ (KFT)} \qquad \text{(Eq. 16-22)}$$



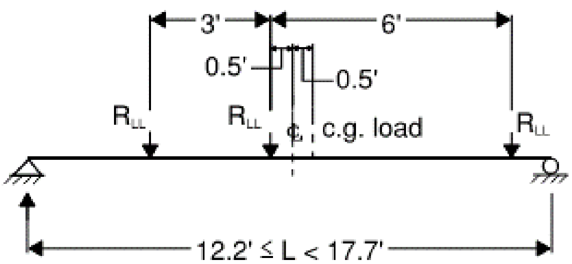
2 WHEEL LINES

$$\text{(1 - lane) } M_{LL} = 2R_{LL}\frac{L/2 - 1.5'}{L}(L / 2 - 1.5)$$

$$= R_{LL}\frac{(L - 3)^2}{2\,L} \quad \text{(KFT)} \qquad \text{(Eq. 16-23)}$$

$$\text{(2 - lane) } M_{LL} = R_{LL}\frac{L/2 - 0.75'}{L}(L / 2 - 0.75)$$

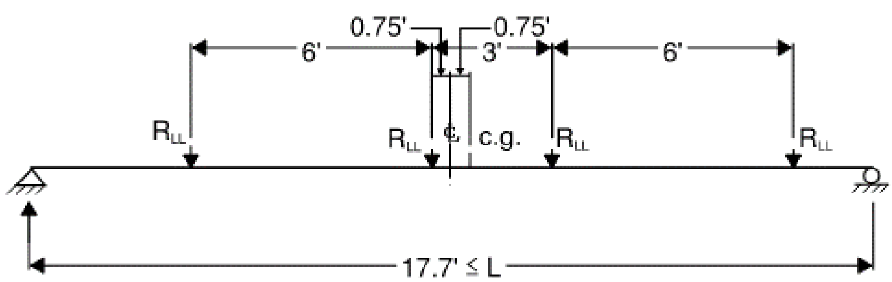
$$= R_{LL}\frac{(L - 1.5)^2}{2\,L} \quad \text{(KFT)} \qquad \text{(Eq. 16-24)}$$



3 WHEEL LINES

$$M_{LL} = 3*R_{LL}\frac{L/2 - 0.5'}{L}(L / 2 - 0.5) - R_{LL} * 3'$$

$$= R_{LL}(0.75 * L - 4.5' + 0.75 / L) \text{ (KFT)} \qquad \text{(Eq. 16-25)}$$



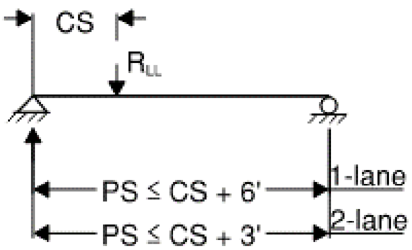
4 WHEEL LINES

$$M_{LL} = 4*R_{LL}\frac{L/2 - 0.75'}{L}(L / 2 - 0.75) - R_{LL} * 6'$$

$$= R_{LL}(L - 9' + 2.25 / L) \quad \text{(KFT)} \qquad \text{(Eq. 16-26)}$$

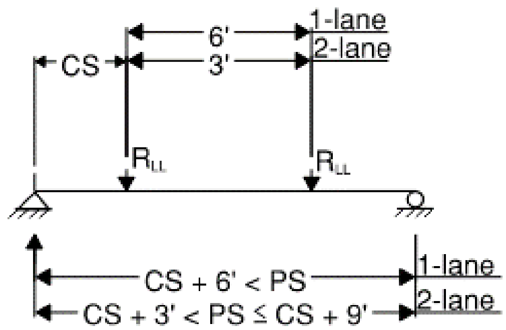
Figure 20: Live Load Moments for Caps (Timber)

1 WHEEL LINE



$$V_{LL} = R_{LL} * K_S * \frac{PS - CS}{PS} \qquad \text{(Eq. 16-27)}$$

2 WHEEL LINES



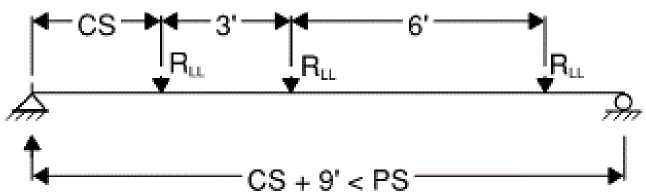
1 - lane

$$V_{LL} = 2 * R_{LL} * K_S * \frac{PS - CS - 3'}{PS} \qquad \text{(Eq. 16-28)}$$

2 - lane

$$V_{LL} = 2 * R_{LL} * K_S * \frac{PS - CS - 1.5'}{PS} \qquad \text{(Eq. 16-29)}$$

3 WHEEL LINES



$$V_{LL} = 3 * R_{LL} * K_S * \frac{PS - CS - 4'}{PS} \qquad \text{(Eq. 16-30)}$$

NOTES:

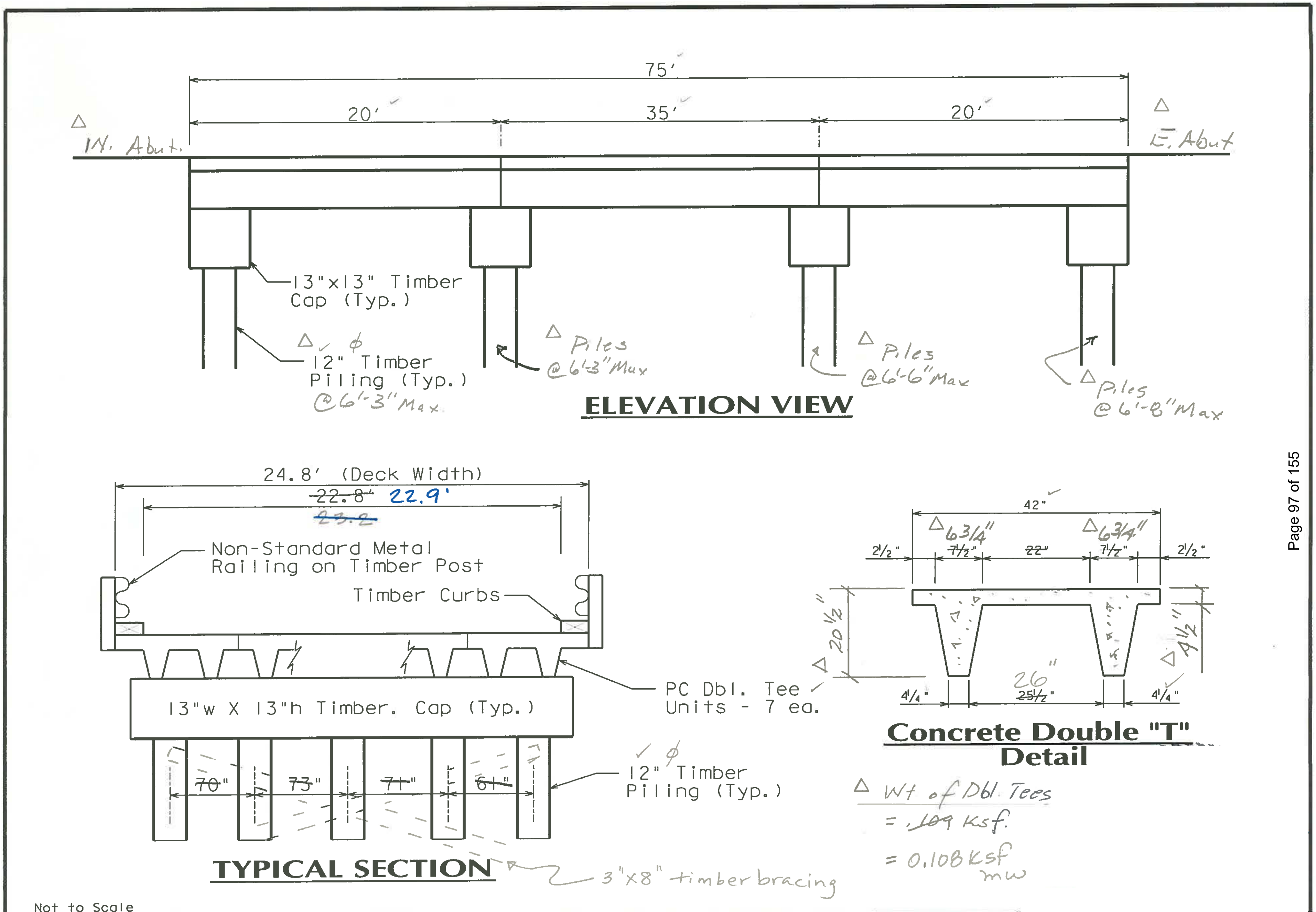
V_{LL} = Live Load Shear (KIPS) R_{LL} = Wheel Line Reaction (KIPS)

H = Cap Height (FT) PS = Pile Spacing (FT)

CS = Distance to Critical Section = $\frac{PS / 4 + 3 * H}{2}$ (FT)

KS = Effective Horizontal Shear Factor = $\frac{10}{9} * \frac{(CS / H)^2}{2 + (CS / H)^2}$

Figure 21: Live Load Shear for Caps (Timber)



BRIDGE SKETCH **BRIDGE NO.** **AA0167-002**

ROAD **CR 1170** (USFS Rd 511)

CREEK **Sikes Creek**

Texas Department of Transportation

TBLRP-LFR Spreadsheet

Timber Cap (ASD)

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Lufkin (11)	AADT ®:	50 # of Lanes: 1
County:	Houston (114)	Truck % (1% MIN):	1%
Structure # :	AA01-67-002	EV Daily Crossing:	1 (1 or 10) One Direction
Location:	CR 1170 Over Sikes Creek	Year Built:	1999
		Cap Descr:	13" x 13" Timber Cap

Cap Inputs

DATA INPUT TABLE	
Bent ID Number:	3
Pile Spacing (ft):	6.50
Equivalent Length Factor:	0.80
Cap Unit Weight (kcf):	0.050
Cap Width (in):	13.000
Cap Height (in):	13.000
Notched Height (in):	
Cap Condition:	Good
Abutment or Int. Bent:	Int. Bent
Adjacent Span Length 1 (ft):	35.00
Adjacent Span Length 2 (ft):	20.00
Superstructure Material Type:	Concrete
Is Superstructure Continuous Over Cap:	No

DEAD LOAD CALCS	
Effective Deck Length for Dead Loads (ft):	27.50
Deck Type:	Concrete Deck
Deck+Fill+Wear. Surface (ksf):	0.056
Superstructure Type:	Concrete Girder
Superstructure Member Spacing (in):	21.000
Superstructure Member Weight (klf):	0.094
Cap Weight (klf):	0.059
Total Dead Load (klf):	**3.076**
MISC. CAP ANALYSIS PROPERTIES	
Equiv. Simple Span Length (ft):	5.20
K:	1.00
Effective Cap Height (in):	13.000
Allowable Bending Stress, F_b (ksi):	1.600
Allowable Shear Stress, F_v (ksi):	0.165
S_x (in^3):	366.167
Distance to Critical Section (ft):	2.44
Effective Horizontal Shear Factor, K_S:	0.796

Analysis

Moment Analysis	
Max H15 Reaction (k):	13.8
Max HS15 Reaction (k):	20.1
M_{ALL} (k-ft):	48.8
M_{DL} (k-ft):	10.4
[Max H15] - M_{LL} (k-ft):	17.9
IR (H15):	32.1
IR (HS15):	22.1
OR (H15):	46.8
OR (HS15):	32.1

Shear Analysis	
Max H15 Reaction (k):	13.8
Max HS15 Reaction (k):	20.1
V_{ALL} (k):	18.6
V_{DL} (k):	6.7
[Max H15] - V_{LL} (k):	6.9
IR (H15):	26.0
IR (HS15):	17.9
OR (H15):	40.7
OR (HS15):	27.9

Additional Notes

Year, Bridge Condition, and Traffic Values assumed.

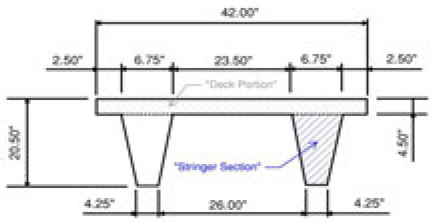
€ - Shear Controls Ratings
¥ - Based on H-20 Rating
£ - Shear Controls Ratings

€ HS Ratings			
HS Inventory:	HS 17.9	RF= 0.89	
HS Operating:	HS 27.9	RF= 1.40	
¥£ H RATING			
H Inventory:	H 26.0	RF= 1.30	
H Operating:	H 40.7	RF= 2.03	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	1.51	TYPE 3:	1.77
SU_5 Operating:	1.43	TYPE 3S2:	1.75
SU_6 Operating:	1.29	TYPE 3-3:	1.85
SU_7 Operating:	1.21	NRL:	1.16
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.55	EV_3 Operating:	0.99

Values calculated based on Allowable Stress Method

Timber Cap

Inputs



Reference visual above for Dead Load Inputs

Pile Spacing:	6.50	ft
Equivalent Length Factor:	0.80	
Timber Cap Unit Weight:	0.050	kcf
Cap Width:	13.000	in
Cap Height:	13.000	in
Notched Height (No Notch):	"left blank"	
Timber Cap Condition:	Good	
Abutment or Int. Bent:	Int. Bent	
Adjacent Span Length 1:	35.00	ft
Adjacent Span Length 2:	20.00	ft
Superstructure Material Type:	Concrete	
Is Superstructure Continuous Over Cap:	No	
Allowable Bending Stress, F_b:	1.600	ksi
Allowable Shear Stress, F_v:	0.165	ksi

Concrete Tee Beam (Deck Portion) Thickness:	4.500	in
Deck+Fill+Wear. Surface:	0.056	ksf
*Calc = [(4.5 in / 12 in * 1 ft) * 0.150 kcf]*		
Superstructure Member Spacing:	21.000	in
Calc = (42.000 in / 2 Stringer Sections)		
Superstructure Member Weight:	0.094	klf
*Calc = ([(4.50 in * 16 in) + (2 * 16.0 in * 1.125 in / 2)] / 144 in ^{2} * 1 ft ^{2}) * 0.150 kcf*		

Additional Properties Used in Analysis

Effective Deck Length for Dead Loads =	(35.00 ft + 20.00 ft) / 2	=	27.50	ft
Eff. Cap Height =	(Notched Cap Height / Cap Height)^2 * (Cap Height)			
Eff. Cap Height =	(13.000 in / 13.000 in)^2 * 13.000 in	=	13.000	in
S_x (in^3) =	(1/6) * Cap Width * (Eff. Cap Height)^2 = (1/6) * 13.000 in * (13.000 in)^2	=	366.167	in^3
Equivalent Simple Span Length, L (ft) =	6.50 ft [pile spacing] * 0.80	=	5.20	ft

Dead Loads

Deck (k/ft) =	(0.056 ksf) * 27.50 ft	=	1.540	klf
(Transverse Loading) Stringers (k/ft) =	0.094 klf * 27.50 ft / (21.000 in * (1 ft / 12 in))	=	1.477	klf
Timber Cap Weight (k/ft) =	(13.000 in) * (13.000 in) * (1 ft^2 / 144 in^2) * 0.050 kcf	=	0.059	klf
Total Dead Load (k/ft) =	1.540 klf + 1.477 klf + 0.059 klf	=	3.076	klf

Moment Analysis

M_{ALL} =	F_b * S_x = 1.600 ksi * 366.167 in^3 * (1 ft / 12 in)	=	48.8	k-ft
M_{DL} =	(1/8) * Total Dead Load (k/ft) * L (ft)^2			
M_{DL} =	(1/8) * 3.076 klf * 5.20 ft * 5.20 ft	=	10.4	k-ft
H15 Wheel Line reaction (k) =	(12 k + 3 k * (Largest Dist. ft -14 ft) / (Largest Dist. ft))			
H15 Wheel Line reaction (k) =	(12 k + 3 k * (35.00 ft -14 ft)/(35.00 ft))	=	13.8	k
HS15 Wheel Line reaction (k) =	[12 k * (2 * Lrg. Dist. ft -14 ft) / (Lrg. Dist. ft)] + [3k * (Small Dist. ft - 14 ft) / (Small Dist. ft)]			
HS15 Wheel Line reaction (k) =	[12 k * (2 * 35.00 ft -14 ft) / (35.00 ft)] + [3k * (20.00 ft - 14 ft) / (20.00 ft)]	=	20.1	k
H15 M_{LL} =	H15 Reaction * Equivalent Simple Span Length / 4 = (13.8 k) * (5.20 ft) / 4	=	17.9	k-ft
HS15 M_{LL} =	HS15 Reaction * Equivalent Simple Span Length / 4 = (20.1 k) * (5.20 ft) / 4	=	26.1	k-ft
Inventory H Rating =	15 * ((48.8 k-ft - 10.4 k-ft) / (17.9 k-ft)	=	**H 32.1**	
Operating H Rating =	15 * ((1.36) * 48.8 k-ft - 10.4 k-ft) / (17.9 k-ft)	=	**H 46.8**	
Inventory HS Rating =	15 * ((48.8 k-ft - 10.4 k-ft) / (26.1 k-ft)	=	**HS 22.1**	
Operating HS Rating =	15 * ((1.36) * 48.8 k-ft - 10.4 k-ft) / (26.1 k-ft)	=	**HS 32.1**	

Note: Values above are rounded (not all decimals shown).

Timber Cap

Shear Analysis

Critical Section, CS =	(Pile Spacing ft / 4 + 3 * Cap Height in * (1 ft / 12 in) * (1/2)			
Critical Section, CS =	(6.50 ft / 4 + 3 * 13.000 in* (1 ft / 12 in) * (1/2)	=	2.44	ft
Effect. Horiz. Shear Factor, KS =	[10/9] * [(CS ft)^2 / (Cap Eff. Height ft)^2] / [2+(CS ft)^2 / (Cap Eff. Height ft)^2]			
Effect. Horiz. Shear Factor, KS =	[10/9] * [(2.44 ft)^2 / (1.083 ft)^2] / [2+(2.44 ft)^2 / (1.083 ft)^2]	=	0.796	

Shear Analysis Calculations

V_{ALL} =	(2/3) * Cap Width (in) * Eff. Cap Height (in) * Fv			
V_{ALL} =	(2/3) * 13.000 (in) * 13.000 (in) * 0.165 ksi	=	18.6	k
V_{DL} =	([Pile Spacing (ft) / 2] - Cap Height (ft)) * Total Dead Load (k/ft)			
V_{DL} =	([6.50 ft / 2] - 1.083 ft) * 3.076 k/ft	=	6.7	k
H15 Wheel Line reaction (k) =	(12 k + 3 k * (Largest Dist. ft -14 ft) / (Largest Dist. ft))			
H15 Wheel Line reaction (k) =	(12 k + 3 k * (35.00 ft -14 ft)/(35.00 ft))	=	13.8	k
HS15 Wheel Line reaction (k) =	[12 k * (2 * Lrg. Dist. ft -14 ft) / (Larg. Dist. ft)] + [3k * (Small Dist. ft - 14 ft) / (Small Dist. ft)]			
HS15 Wheel Line reaction (k) =	[12 k * (2 k * 35.00 ft -14 ft) / (35.00 ft)] + [3k * (20.00 ft - 14 ft) / (20.00 ft)]	=	20.1	k
H15 V_{LL} =	H15 Reaction * Effect. Horiz. Shear Factor * (Pile Spacing - Critical Section) / Pile Spacing			
H15 V_{LL} =	13.8 k * 0.796 * (6.50 ft - 2.44 ft) / 6.50 ft	=	6.9	k
HS15 V_{LL} =	HS15 Reaction * Effect. Horiz. Shear Factor * (Pile Spacing - Critical Section) / Pile Spacing			
HS15 V_{LL} =	20.1 k * 0.796 * (6.50 ft - 2.44 ft) / 6.50 ft	=	10.0	k
Inventory H Rating =	15 * ((18.6 k - 6.7 k) / (6.9 k)	=	**H 26.0**	**<<<**
Operating H Rating =	15 * ((1.36) * 18.6 k - 6.7 k) / (6.9 k)	=	**H 40.7**	**<<<**
Inventory HS Rating =	15 * ((18.6 k - 6.7 k) / (10.0 k)	=	**HS 17.9**	**<<<**
Operating HS Rating =	15 * ((1.36) * 18.6 k - 6.7 k) / (10.0 k)	=	**HS 27.9**	**<<<**

Note: Values above are rounded (not all decimals shown).

Section 17: Steel Pile

1. **DATA INPUT TABLE**
    a. ***Pile ID Number*** - The Pile ID should correspond with the bent numbers and inventory direction used on the bridge plans or inventory record.
    b. ***Standard Pile Designation*** – Select a beam designation from the dropdown list.
        i. The dropdown list has been compiled from the AISC publication Iron and Steel Beams 1873 to 1972, otherwise known as *Historical Record, Dimensions and Properties, Rolled Shapes, Steel and Wrought Iron Beams & Columns, As Rolled in U.S.A., Period 1873 to 1972, With Sources as Noted*, compiled and edited by Herbert W. Ferris. The dropdown list also consists of the HP, S, and W-Shapes as provided by the AISC Shapes Database (V16.0).
        ii. The selected designation will populate the section dimensions below.
            1. Each section dimension can be overwritten to be the "remaining section" if section loss is present at the Engineer's discretion.
        iii. A new pile designation can be created by inputting all of the section dimensions.
            1. ***Rolled Section Depth (in)*** – Input the rolled section depth of the pile.
            2. ***Web Thickness (in)*** – Input the pile web thickness.
            3. ***Flange Width (in) –*** Input the pile flange width.
            4. ***Top Flange Thickness (in) –*** Input the pile top flange thickness.
            5. ***Bottom Flange Thickness (in) –*** Input the pile bottom flange thickness.
            6. ***Fillet Radius (in) –*** Input the fillet radius of the pile.
        iv. Selecting 'Circular Pipe' will allow the user to input the Outer and Inner Diameters of the Pipe. The Wall Thickness is then calculated.
    c. ***Pile Moment of Inertia, [Ix/Iy] (in^4)*** – Calculated from the section dimensions.
    d. ***F_y (ksi)*** – Input the yield stress of the steel pile. If unknown, this value is recommended based upon the date built, as seen in *Appendix A.*
    e. ***Cap Elastic Modulus (ksi) –*** Input the elastic modulus of the cap.
    f. ***Unbraced Pile Length (L_x) (ft)*** – Input the unbraced pile length about the x-axis.
    g. ***Unbraced Pile Length (L_y) (ft)*** – Input the unbraced pile length about the y-axis.
    h. ***K_x*** – Equivalent length factor about x-axis. (*Figure 22: Equivalent Length Factors*)
    i. ***K_y*** – Equivalent length factor about y-axis. (*Figure 22: Equivalent Length Factors*)
    j. ***Number of Piles*** – Input number of piles the cap is bearing on. The Pile Spacing Input Table to the right of the printed area will update with the number of bays. Input each pile bay spacing.
    k. ***Distance to First Pile from Edge of Cap (ft)*** – Enter distance from edge of cap to the first pile.
    l. ***Abutment or Int. Bent –*** Select whether the steel cap is located at an abutment or interior bent.

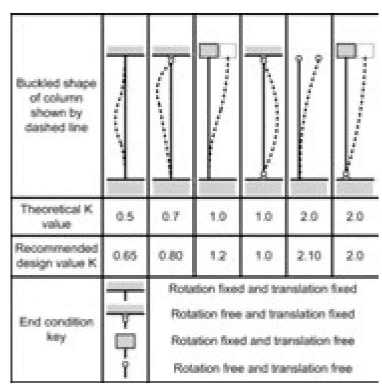


Figure 22: Equivalent Length Factors

m. ***Adjacent span Length 1 (ft) –*** Input the first adjacent span length.
n. ***Adjacent span Length 2 (ft) [Int. Bent Only] –*** Input the second adjacent span length.

2. **IMPORT FROM CAP MODULE**
    a. Cap Module - Select Steel Cap or Timber Cap to import values into the Steel Pile module.
        i. Select "No Import" when not utilizing values from another cap module.
        ii. Values will update only when value is selected from drop-down option.
3. **DECK INPUTS**
    a. ***Deck Type*** – Select the deck type and input the following deck inputs.
        i. If a deck module is available to import, it will import the Deck Thickness and Deck+Fill+Wear. Surface.
        ii. To input a concrete slab superstructure (i.e., flat slabs), select 'Concrete Slab' and input as the deck. The superstructure inputs will then be uneditable.
    b. ***Deck Thickness (in)*** – Input the deck thickness.
    c. ***Deck Elastic Modulus, E (ksi)*** – Input the elastic modulus of the deck.
    d. ***Deck+Fill+Wear. Surface (ksf)*** – Enter the total deck weight including deck, fill, wearing surface, and miscellaneous loads.
        i. Dead loads from defined deck modules can be found in the table to the right.
    e. ***Deck Width (ft) –*** Input the deck width.
4. **SUPERSTRUCTURE INPUTS**
    a. ***Superstructure Type*** – Select the superstructure type and input the following superstructure inputs.
        i. If a superstructure module is available to import, it will import the Stringer Weight and Stringer Spacing.
    b. ***Stringer Weight (klf)*** – Enter the stringer weight with all miscellaneous loads.
        i. Stringer weights from defined superstructure modules can be found in the table to the right.
    c. ***Number of Stringers*** – Enter number of stringers bearing on the cap.
    d. ***Distance to First Stringer from Edge of Deck (ft)*** – Enter the distance from the edge of deck to the first stringer (i.e. the deck overhang).
    e. ***Stringer Spacing (in)*** – Enter average stringer spacing on the cap.
        i. Stringer spacing from defined superstructure modules can be found in the table to the right.
5. **CAP INPUTS**
    a. ***Cap Type*** – Select the cap type and input the following cap inputs.
    b. ***Cap Length (ft)*** – Input the total cap length.
    c. ***Cap Weight (ft)*** – Input the cap weight.
    d. ***Cap Moment of Inertia (in^4)*** – Input the cap moment of inertia.
6. **RUN PILE ANALYSIS**
    a. Push the 'Run Pile Analysis' button when all information in Data Input Table, Deck Inputs, Superstructure Inputs, and Cap Inputs have been input. Validation checks will run to ensure data was input correctly and a message box will notify the user of critical errors.
    b. Select "Yes" from the dropdown to print additional information regarding the reactions, shear, and moments generated in the Pile Analysis.

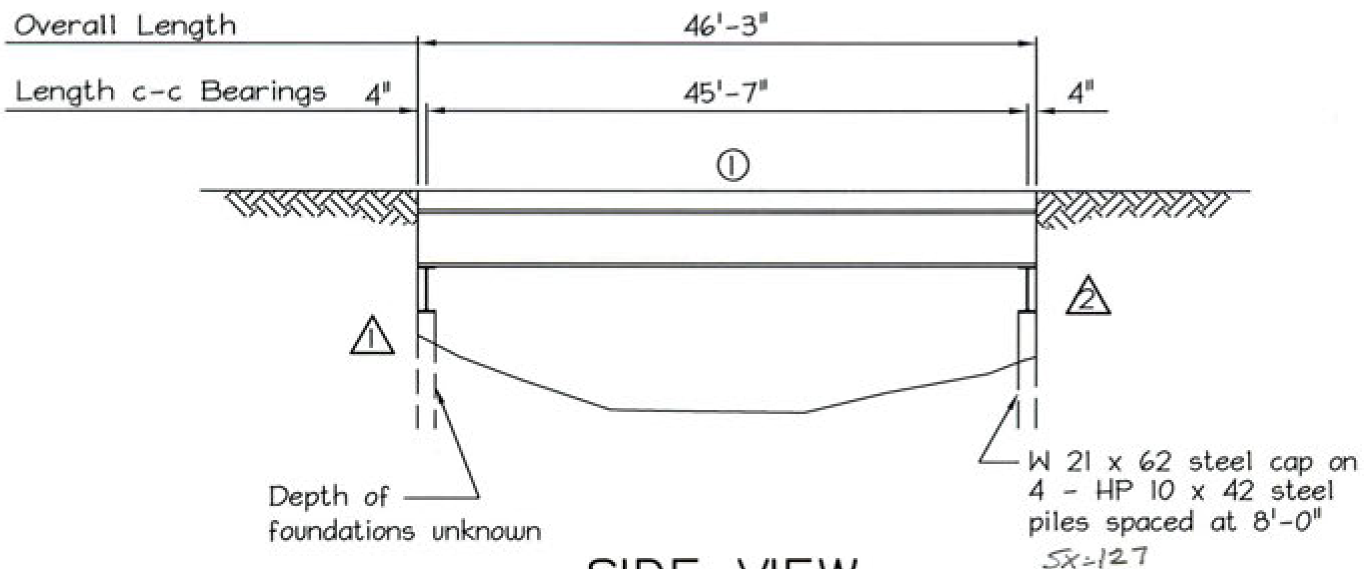
    i. This must be selected prior to selecting "Run Pile Analysis".
    ii. If left blank or "No" is selected, the detailed print table at Cell O200 will be left blank when analysis is run.

7. **ANALYSIS**
    a. ***Dead and Live Load Analysis***
        i. TBLRP-LFR estimates the live load shear and moments for continuous systems by using influence lines. The influence lines are calculated using Muller-Breslau's principle, see *Appendix F*. Each element in the continuous system is divided in ten (10) segments. Once the element is segmented, an influence line for each section at the end of each segment is calculated, ten (10) per segment. For example, a three-span continuous system will have a total of 30 segments and 29 sections. The sections at the exterior supports are not considered. Also, the shared section between elements is considered only once. In this example, 29 influence lines will be computed.
        TBLRP-LFR includes eight standard trucks, H20, HS20, SHVs (4), EVs (2), for estimating the live load shears and moments acting in the continuous span model. For each truck, the live load shear/moment at each section is estimated from its influence line by multiplying each truck axle's weight times the corresponding influence line ordinate at the location of each truck axle as it moves along each span in the model. These values are tabulated and used to estimate the maximum live load shear and moment at each section.
        The loads bearing on each pile can then be calculated and rating factors are computed and reported.
            1. Additional information on the analysis performed can be found to the right of the printed section.
    b. ***Pile Capacity*** – Select the method of pile capacity analysis. Input an 'X' to indicate the method.
        i. ***Pile Design Strength-LFR*** – Calculated with the provisions of *AASHTO 10.54.1.1* assuming AASHTO Eqn. 10-151 governs.
        ii. ***Pile Subsurface Capacity (assumed)-ASR*** – Produces an allowable stress rating with the rating factors calculated without factors.
            1. Where design pile capacity is not known, and it is not feasible to do subsurface investigations or load test, the subsurface capacity may conservatively be taken as 4 kips/inch of pile section depth.
        iii. ***Pile Capacity (see attached calculations)*** – Can be input when capacity calculations have been performed outside of TBLRP-LFR. Attach a copy of the calcs with the load rating.

General Notes:

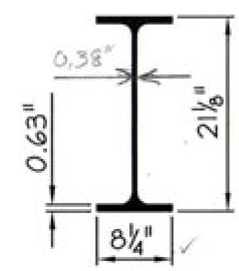
- Changing any of the inputs in the Data Input Table, Deck Inputs, Superstructure Inputs, or Cap Inputs tables will cause the analysis results to delete. The analysis will then need to re-run.
- Full Analysis results are shown in the table located at Cell O116. Values are in k-in for moments and kips for shear.
- Rating factor calculations are shown in the table located at Cell AI116 for the controlling section of each truck.

District 13 County 143 Cont.-Sec. AA01-75 Structure 001 Route CR 280

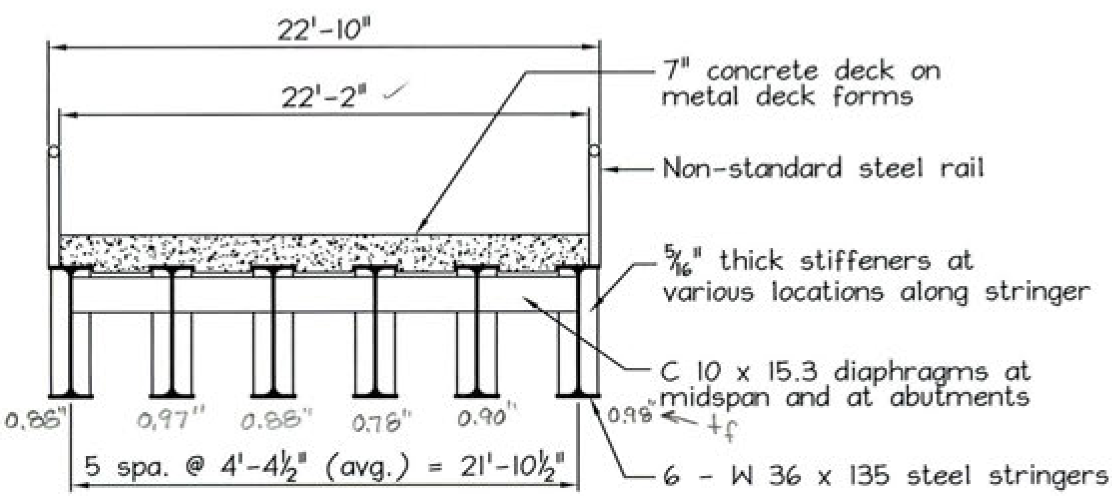


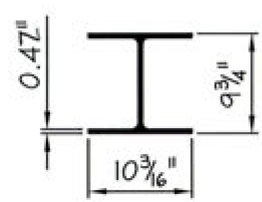
SIDE VIEW
(Looking West)

LEGEND
- ○ Span Numbers
- △ Abutment Numbers
- □ Bent Numbers
- C Continuous
- S Simple Support



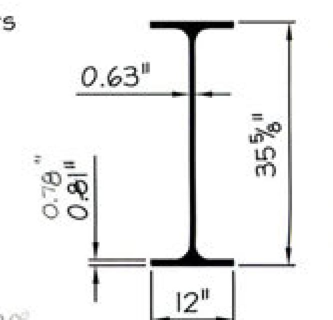
W 21 x 62
Steel cap





HP 10 x 42
Steel pile

SPAN 1
(Looking South)



Most are W36x150
W 36 x 135
Steel stringer
(Min. Dimensions Shown)

TBLRP-LFR Spreadsheet

Steel Pile

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Yoakum (13)	AADT ®:	50 — # of Lanes: 1
County:	Lavaca (143)	Truck % (1% MIN):	1%
Structure # :	AA01-75-001	EV Daily Crossing:	1 (1 or 10) One Direction
Location:	CR 280 Over Ponton Creek	Year Built:	2005
		Pile Descr:	HP10x42 Interior Steel Pile at Bent 1

Pile Inputs

DATA INPUT TABLE		
Pile ID Number:		2
Standard Pile Designation:		HP10X42
Rolled Section Depth (in):		9.700
Web Thickness (in):		0.415
Flange Width (in):		10.100
Top Flange Thickness (in):		0.420
Bottom Flange Thickness (in):		0.420
Fillet Radius (in):		0.500
Pile Moment of Inertia, Ix (in4):		210.84
Fy (ksi):		36.0
Cap Elastic Modulus (ksi):		29000.0
Unbraced Pile Length (ft):	Lx = 10.00	Ly = 10.00
K_x:	1.000	K_y: 1.000
Number of Piles:		4
Distance to First Pile from Edge of Cap (ft):		0.50
Abutment or Int. Bent		Abutment
Adjacent Span Length 1 (ft):		46.25
Adjacent Span Length 2 (ft):		0.00

DECK INPUTS	
Deck Type:	Concrete Deck
Deck Thickness (in):	7.000
Deck Elastic Modulus, E (ksi):	3122.0
Deck+Fill+Wear. Surface (ksf):	0.088
Deck Width (ft):	22.83
SUPERSTRUCTURE INPUTS	
Superstructure Type:	Steel Stringer
Stringer Weight (klf):	0.135
Number of Stringers:	6
Distance to First Stringer from Edge of Deck (ft):	0.48
Stringer Spacing (in):	52.500
CAP INPUTS	
Cap Type:	Steel Cap
Cap Length (ft):	25.00
Cap Weight (klf):	0.062
Cap Moment of Inertia (in4):	1333.8

Analysis

Pile Capacity		
		Type "X" to indicate method:
Pile Design Strength - LFR		
ΦP_n =	349.3 k	x
Pile Allowable Subsurface Capacity (assumed) - ASR		
P_{sub} =		
Pile Capacity (see attached calculations)		
P =		

Detailed Analysis Print:	No

Pile Spacing (ft):	8 - 8 - 8

Loads on Controlling Pile

	Pile	LL w/o IM (k)	DL (k)
HS:	2	46.2	24.7
SU_4:	2	37.5	24.7
SU_5:	2	41.5	24.7
SU_6:	2	43.5	24.7
SU_7:	2	45.1	24.7
EV_2:	2	39.8	24.7
EV_3:	2	59.2	24.7
T3:	2	33.9	24.7
T3S2:	2	34.8	24.7
T3-3:	2	32.8	24.7
NRL:	2	45.0	24.7

Additional Notes

Cap length assumed to be 25'-0".

€ - Analysis Based Upon Load Factor Method

¥ - Based on H-20 Rating

£ - Analysis Based Upon Load Factor Method

€ HS Ratings			
HS Inventory:	HS 48.7	RF= 2.43	
HS Operating:	HS 81.3	RF= 4.06	
¥£ H RATING			
H Inventory:	H 75.0	RF= 3.75	
H Operating:	H 125.2	RF= 6.26	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	5.00	TYPE 3:	5.54
SU_5 Operating:	4.52	TYPE 3S2:	5.40
SU_6 Operating:	4.32	TYPE 3-3:	5.72
SU_7 Operating:	4.16	NRL:	4.18
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	4.71	EV_3 Operating:	3.17

See Formula 6-1a (MCEB) for the general Rating Formula.

Steel Pile

Inputs

Standard Pile Designation:	HP10X42	Deck Type:	Concrete Deck
Rolled Section Depth:	9.700 in	Deck Thickness:	7.000 in
Web Thickness:	0.415 in	Deck Elastic Modulus, E:	3122.0 ksi
Flange Width:	10.100 in	Deck+Fill+Wear. Surface:	0.088 ksf
Top Flange Thickness:	0.420 in	Deck Width:	22.83 ft
Bottom Flange Thickness:	0.420 in	SUPERSTRUCTURE INPUTS	
Fillet Radius:	0.500 in	Superstructure Type:	Steel Stringer
Pile Moment of Inertia:	210.84 in^4	Stringer Weight:	0.135 klf
F_y:	36.0 ksi	Number of Stringers:	6
Cap Elastic Modulus:	29000.0 ksi	Distance to First Stringer from	
Unbraced Pile Length:	L_x = 10.00 ft	Edge of Deck:	0.48 ft
	L_y = 10.00 ft	Stringer Spacing:	52.500 in
K_x:	1.000	CAP INPUTS	
K_y:	1.000	Cap Type:	Steel Cap
Number of Piles:	4	Cap Length :	25.00 ft
Distance to First Pile from Edge of Cap:	0.50 ft	Cap Weight:	0.062 klf
Abutment or Int. Bent	Abutment	Cap Moment of Inertia:	1333.8 in^4
Adjacent span Length 1:	46.25 ft	Pile Spacing:	8 - 8 - 8 ft
Adjacent span Length 2:	0.00 ft		

Capacity ('Pile Design Strength - LFR' option selected)

Pile Area, AG (in^2) = Area of Top/Bot Flanges + Area Web + (Fillet Radius Area *4)

Pile Area, AG (in^2) = 4.24 in^2 + 4.24 in^2 + 3.68 in^2 + (0.05 in^2 * 4) = 12.38 in^2

Strength Capacity Calculations

Slenderness Ratio = (K factor) * (Pile Height (in) / (Pile Diameter * π / 4) = K_xL_x/r_x

About x-axis:

K_xL_x/r_x = 1.0 * 10.00 ft * (12 in / 1 ft) / 4.128 in = 29.07

AASHTO EQ. 10-152 = √(2 * π^2 * 29000 ksi / 36.0 ksi) = 126.099 <<<

Since AASHTO EQ. 10-152 > $K_x L_x / r_x$, use AASHTO EQ. 10-151: $F_{cr} = F_y [1 - F_y/(4*\pi^2*E)*(KL_c/r)^2]$

F_{cr} = 36.0 [1-36.0 ksi/(4*π^2*29000 ksi)* $(29.07)^2$] = 35.043 ksi

About y-axis:

K_yL_y/r_y = 1.0 * 10.00 ft * (12 in / 1 ft) / 2.415 in = 49.69

AASHTO EQ. 10-152 = √(2 * π^2* 29000 ksi / 36.0 ksi) = 126.099 <<<

Since AASHTO EQ. 10-152 > $K_x L_x / r_x$, use AASHTO EQ. 10-151: $F_{cr} = F_y [1 - F_y/(4*\pi^2*E)*(KL_c/r)^2]$

F_{cr} = 36.0 [1-36.0 ksi/(4*π^2*29000 ksi)* $(49.69)^2$] = 33.205 ksi <<<

ΦP_n = 0.85 *Pile Area * F_{cr} = 0.85 * 12.38 in^2 * 33.21 ksi = 349.3 k

Analysis

TBLRP-LFR estimates the dead and live load shears/moments for continuous systems (stringers, caps, etc) by using influence lines. See Appendix B for more information.

	Span	DL	HS20
Pile	1	8.7	16.3
Pile	2	24.7	46.2
Pile	3	24.7	45.5
Pile	4	8.7	11.9

Rating Factors

Axial Compression

HS-20 INV RF = (349.3 k - 1.3 * 24.7 k)/(2.17 * 46.2 k * 1.3) = 2.43

HS 48.7 <<<

HS-20 OPR RF = (349.3 k - 1.3 * 24.7 k)/(1.3 * 46.2 k * 1.3) = 4.06

HS 81.3 <<<

Note: Values above are rounded (not all decimals shown).

Section 18: Timber Pile

1. **DATA INPUT TABLE**
    a. ***Pile ID Number*** – The Pile ID should correspond with the pile numbers used on the bridge plans or inventory record.
    b. ***Interior or Exterior Pile*** – Select whether the pile is an interior pile or exterior pile.
        i. When Interior Pile is selected*:*
            1. ***Interior Pile Spacing – 1 (ft)*** – Input the distance to one of the adjacent piles (centerline to centerline).
            2. ***Interior Pile Spacing – 2 (ft)*** – Input the distance to the other adjacent pile (centerline to centerline).
        ii. When Exterior Pile is selected*:*
            1. ***Exterior Pile Spacing (ft)*** – Input the distance to the adjacent pile (centerline to centerline).
            2. ***Wheel Load Overhang Distance (ft)*** – Input the wheel load overhang distance for the exterior pile being analyzed (from the pile centerline).
                a. The Wheel Load Overhang Distance is the largest distance that a wheel load is expected to travel outside the centerline of pile.
    c. ***Pile Height (ft)*** – Input the height of the timber pile.
        i. This value will be used to calculate the Slenderness Ratio for the timber pile.
        ii. This value should be the distance from top of the pile to the point in the soil/earth in which the load rater assumes it reaches fixity (if fixity is present).
    d. ***Pile Diameter (in)*** – Input the diameter of the timber pile*.*
    e. ***Section Loss (%)*** – Input the percentage of section loss for the timber pile per the most recent inspection.
    f. ***Pile Unit Weight (kcf)*** – Input the unit weight of the timber pile.
        i. This value is typically around 0.050 kcf for timber.
    g. ***Pile Condition*** - Select the condition of the pile being analyzed.
        i. The Pile Condition is referenced by the allowable compression stress, allowable bending stress, and allowable shear stress cells in the MISC. PILE ANALYSIS PROPERTIES section.
        ii. This condition should be derived from the most recent inspection.
    h. ***Abutment or Int. Bent*** – Select whether the timber pile is located at an abutment or at an intermediate bent.
    i. ***Adjacent Span Length 1 (ft)*** – Input the adjacent span length for an abutment cap or intermediate bent cap.
    j. ***Adjacent Span Length 2 (ft)*** – Input the other adjacent span length for an intermediate bent cap.
        i. This cell turns to 0.00 ft if 'Abutment' is selected above.
    k. ***Effective Length 'K' Factor*** – Select design value 'K'.
        i. Reference for additional guidance.

l. ***Method for Subsurface Capacity*** – This cell is for documentation purposes only and does not impact analysis values. The option selected in this cell should correspond to the Subsurface Capacity, P_{ALL} value present in the MISC. PILE ANALYSIS PROPERTIES section. Select one of the three options from the drop-down list:
    i. Assumed Pile Capacity
    ii. Design Pile Capacity
    iii. Attached Calculations for data input

m. ***Superstructure Material Type*** – Select the material type of the superstructure member(s) transferring their forces to the substructure unit being analyzed.
    i. This input is utilized when considering the effect of negative moments over the pile if the superstructure is defined as 'Continuous' below.

n. ***Is Superstructure Continuous Over Pile*** – Select from the drop-down list whether the superstructure is continuous over the substructure unit.

2. **IMPORT FROM CAP MODULE**
    a. Cap Module – Select Steel Cap or Timber Cap to import values into the Timber Pile module.
        i. Select "No Import" when not utilizing values from another cap module.
        ii. Values will update only when value is selected from drop-down option.

3. **DEAD LOAD CALCS**

    Note: The tables to the right of the printed section can be referenced if deck, superstructure, and cap modules have been previously filled out. Please review and verify these values prior to copying them into the cells within this section.

    a. ***Effective Deck Length for Dead Loads (ft)*** – The value in this cell is calculated based upon the adjacent span length(s) in the DATA INPUT TABLE.
        i. This cell shows the total span being resisted by the pile.
        ii. For piles at abutments, this is half of the Adjacent Span Length 1 value.
        iii. For piles at intermediate bents, this is half of the Adjacent Span Length 1 value plus half of the Adjacent Span Length 2 value.
    b. ***Effective Tributary Deck Width for Dead Loads (ft)*** – Input a value for the effective tributary deck width for dead loads. The value in this cell is automatically calculated based upon the pile spacings and wheel overhang distance (when applicable) values input into the DATA INPUT TABLE.
        i. This cell shows the total width of the structure being resisted by the pile.
        ii. For interior piles, this is half of the Interior Pile Spacing – 1 (ft) value plus half of the Interior Pile Spacing – 2 (ft) value.
        iii. For exterior piles, this is half of the Exterior Pile Spacing (ft) value plus the Wheel Load Overhang Distance (ft) value.
    c. ***Deck Type*** – Select the deck type from the drop-down list.
        i. To input a concrete slab superstructure (i.e. flat slabs), select 'Concrete Slab' and input dead load values below.
        ii. When 'Concrete Slab' is selected, the superstructure inputs for dead loads will become un-editable.
    d. ***Deck+Fill+Wear. Surface (ksf)*** – Enter the total deck weight including fill, wearing surface and any other miscellaneous loads.

e. ***Superstructure Type*** – Select the superstructure type and input the following superstructure inputs.

f. ***Superstructure Member Spacing (in)*** – Enter the average stringer spacing acting on the effective tributary deck width, as calculated above.

   i. Values for this cell should be input from centerline to centerline of superstructure members when possible.

g. ***Superstructure Member Weight (klf)*** – Enter the average superstructure member weight in the longitudinal orientation acting on the effective tributary deck width, as calculated above.

h. ***Cap Type*** – Select the cap material type from the drop-down list associated with the pile being analyzed.

i. ***Cap Weight (klf)*** – Input the cap weight in the transverse orientation.

j. ***Total Dead Load (ksf) –*** This cell calculates the total dead load being applied to the pile based upon the effective length and width values calculated above.

4. **MISC. PILE ANALYSIS PROPERTIES**

a. ***Wheel Line Distribution Factor, DF*** – The Wheel Line Distribution Factors are calculated based upon *Figure 25.*

b. ***Timber Grade*** – Select the timber grade that represents the pile being analyzed.

   i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.

   ii. Refer to *Figure 23* for additional guidance.

c. ***Modulus of Elasticity, E (ksi)*** – Input the Modulus of Elasticity for the pile being analyzed.

   i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.

   ii. Refer to *Figure 23* for additional guidance.

d. ***Allowable Compression Stress (F_c) (ksi)*** – Input a value for the allowable compression stress based upon the most recent bridge inspection performed.

   i. Some recommended values for Southern Pine can be found to the right of the printed page within TBLRP-LFR.

   ii. Refer to *Figure 23* for additional guidance.

Timber Grade	Maximum Grain Slope	Maximum Knot Diameter	Allowable Compression Stress FC (KSI)	Modulus of Elasticity E (KSI)
Select	1 in 14	1/4 pile diameter	1.10	1600
No. 1	1 in 11	1/3 pile diameter	0.92	1600
No. 2	1 in 8	1/2 pile diameter	0.72	1400

The user is advised to reduce these values by 25% for untreated timber as a precaution against rapid progression of decay.

Figure 23: Allowable Compression Stress values for Southern Pine (Caps)

e. **Subsurface Capacity, P_{ALL} (k)** – Input the subsurface capacity of the timber pile.
   i. This value should be based upon the Method for Subsurface Capacity selected.
   ii. If the value is not known, an assumed value of (4 kips/in) x (pile diameter (in)) is a reasonable starting place.
   iii. This value should be adjusted at the Engineer's discretion.

f. **Column Capacity, P_{ALL} (k)** – The column capacity is calculated as follows:

P_{ALL} (k) = Area of Pile (in^2) x Controlling Fc' (ksi) (Eq. 18-1)

The controlling Fc' is based upon the following scenarios:

Depending on the distance between brace points, the allowable compression stress is modified according to the following equations for the Inventory Allowable Compression Stress, Fc'.

If kl/d ≤ 11 then Fc' = Fc (ksi) (Eq. 18-2)

If 11 < kl/d < C where C = 0.671 * (E/Fc)$^{1/2}$ then

$$Fc' = Fc * [1 - \frac{1}{3} * [\frac{\frac{kl}{d}}{C}]^4] \quad \text{(ksi)} \qquad \text{(Eq. 18-3)}$$

If kl/d ≥ C then

$$Fc' = \frac{0.30*E}{(\frac{kl}{d})^2} \quad \text{(ksi)} \qquad \text{(Eq. 18-4)}$$

where k = Effective Length Factor (See Coding Guide)

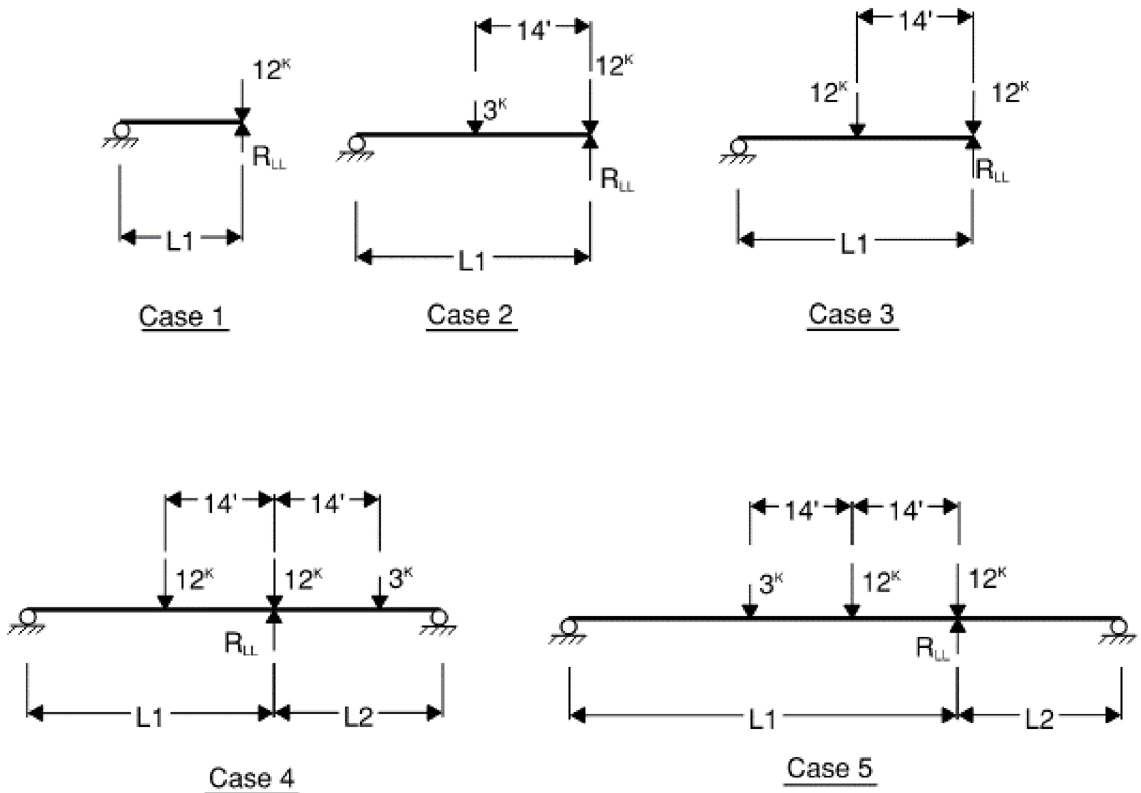
l = Unbraced Length of Pile (in)

d = Pile Diameter (in)

g. **Net Section, P_{ALL} (k)** – The net section (capacity) is calculated as follows:

P_{ALL} (k) = Pile Area (in^2) x Allow. Comp. Stress, Fc (ksi) x (1 - Sect. Loss %) (Eq. 18-5)

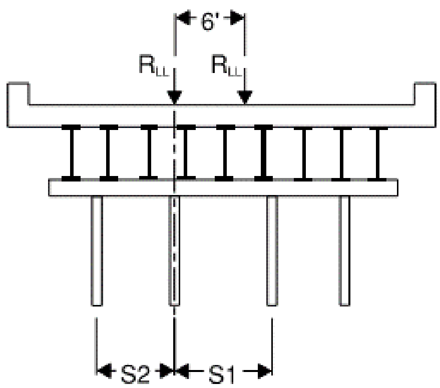
5. **Analysis**
    a. The Timber Pile module uses allowable stress for its analysis, similar to the original TBLRP software.
    b. This module performs a compression analysis of the pile in question.
    c. TBLRP-LFR does not account for lane loading analysis for the Timber Pile. If lane loading is warranted for a specific structure, please load rate the Timber Pile using another method of analysis.
    d. Additional information and a further breakdown of this analysis and of the equations used can be found to the right of the printed section of the software and at the end of this section within the User Guide.
    e. The compression analysis for this module follows a similar logic to the original TBLRP. TBLRP- LFR calculates the maximum compression generated from live loads for H15 and HS15 trucks, along with the maximum compression from dead loads, and uses them to calculate the inventory and operating ratings based upon the calculated allowable compression of the timber pile.
    f. The formulas used in the Compression Analysis section are explained below:
        i. **Max H15 Reaction (k)** is calculated based upon the scenarios outlined in *Figure 24.*
        ii. **Max HS15 Reaction (k)** is calculated based upon the scenarios outlined in *Figure 24.*
        iii. **Pile Capacity, P_{ALL} (k)** - the value seen in this cell is the controlling capacity based upon the Subsurface Capacity check, the Column Capacity check, and the Net Section capacity check.
        iv. **P_{DL} (k)** = Effective Deck Length for Dead Loads (ft) x Effective Tributary Deck Width for Dead Loads (ft) x Total Dead Load (ksf) (Eq. 18-6)
        v. **[Max H15] - P_{LL} (k)** = Max H15 Reaction (k) x LL Distribution Factor (Eq. 18-7)
            1. The LL Distribution Factor is calculated based upon the scenarios outlined in *Figure 25*.
        vi. **IR (H15)** = 15 x (P_{ALL} – P_{DL}) / P_{LL} (Eq. 18-8)
        vii. **IR (HS15)** = IR (H15) x Max H15 Reaction (k) / Max HS15 Reaction (k) (Eq. 18-9)
        viii. **OR (H15)** = 15 x ((1.36) x P_{ALL} – P_{DL}) / P_{LL} (Eq. 18-10)
        ix. **OR (HS15)** = OR (H15) x Max H15 Reaction (k) / Max HS15 Reaction (k) (Eq. 18-11)



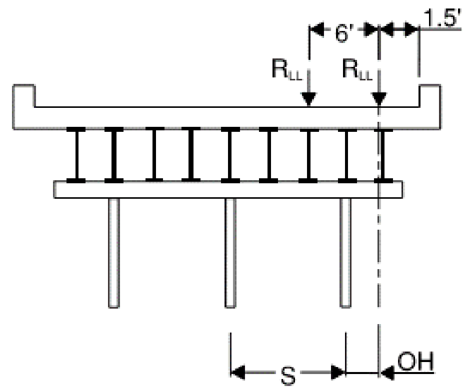
Load Case	Rating Vehicle	L1(FT)	L2(FT)	WHEEL LINE REACTION, R_{LL} (K)	
1	H15	L1 ≤ 14	L2 ≤ L1	RLL = 12	Eq. 18-12
2	H15	L1 > 14	L2 ≤ L1	RLL = 12 + 3.0 (L1 - 14.0) / L1	Eq. 18-13
1	HS15	L1 ≤ 14	L2 ≤ L1	RLL = 12	Eq. 18-14
3	HS15	28 ≥ L1 > 14	L2 ≤ 14	RLL = 12*(2*L1-14) / L1	Eq. 18-15
4	HS15	28 ≥ L1 > 14	L1 ≥ L2 >14	RLL = 12*(2*L1-14) / L1+3 (L2-14) / L2	Eq. 18-16
5	HS15	L1 > 28	L2 ≤ L1 / 2	RLL = 12*(2*L1-14) / L1+3 (L1-28) / L1	Eq. 18-17
4	HS15	L1 > 28	L2 > L1 / 2	RLL = 12*(2*L1-14) / L1+3 (L2-14) / L2	Eq. 18-18

L1 = Larger Distance between adjacent caps (FT)
L2 = Smaller Distance between adjacent caps (FT)
R_{LL} = Wheel Load Reaction (K)

Figure 24: Wheel Load Reactions on Caps [above piles] (Timber)



INTERIOR PILE
(TYPE Int.)

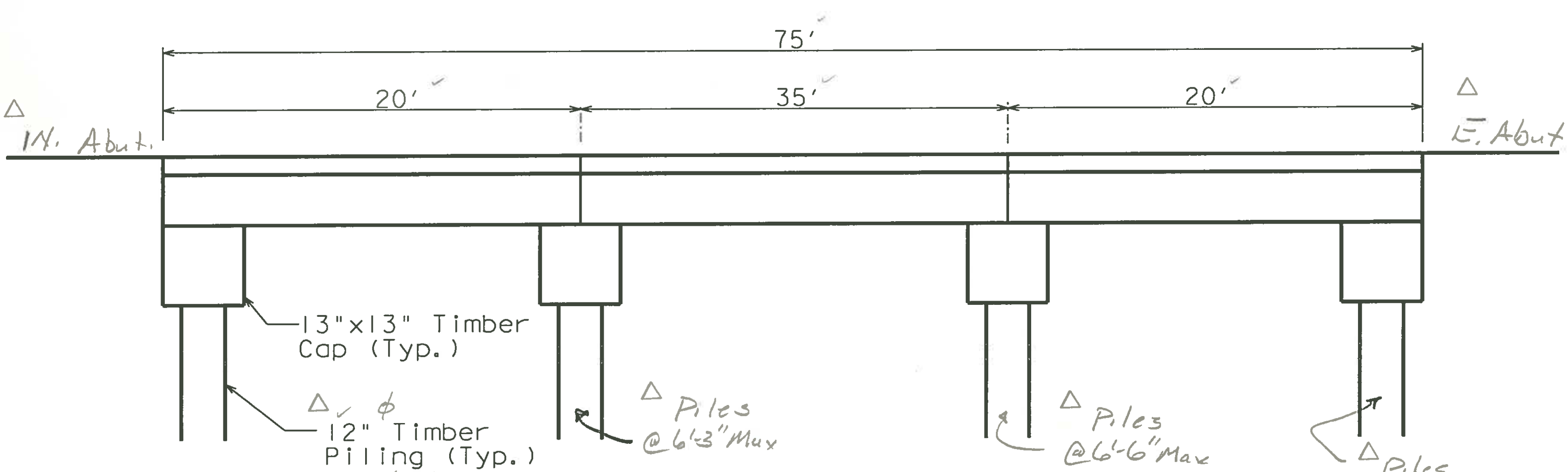


EXTERIOR PILE
(TYPE Ext.)

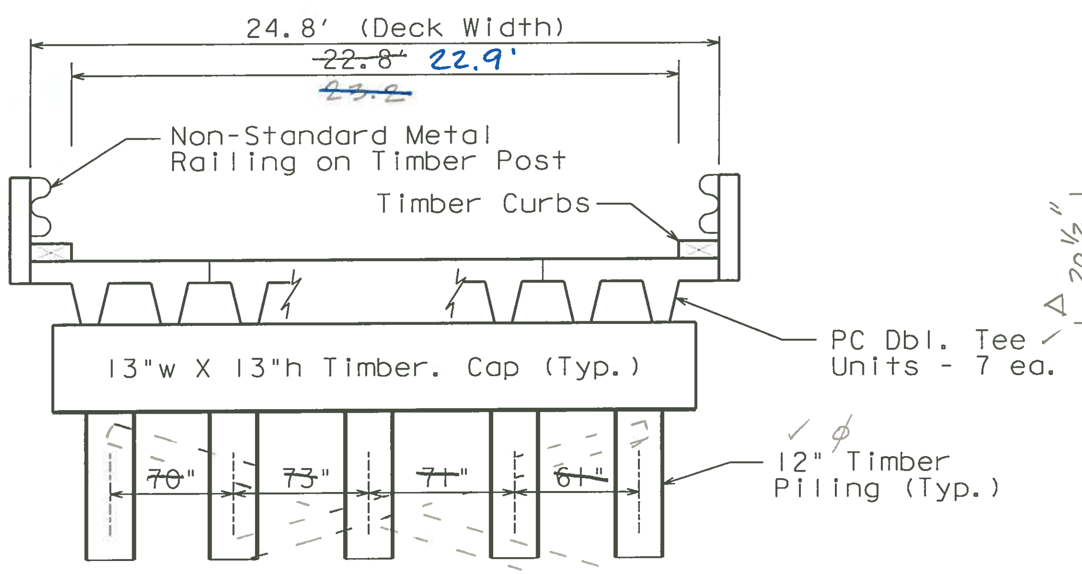
PILE TYPE	NO. OF LANES	S1 or (S + OH)	S2 or OH	WHEEL LINE DISTRIBUTION FACTOR, DF	
Int.	1	S1 ≤ 6'	S2 ≤ S1	DF = 1.0	Eq. 18-19
Int.	1	S1 > 6'	S2 ≤ S1	DF = 1.0 + (S1 - 6) / S1	Eq. 18-20
Int.	2	S1 ≤ 4'	S2 ≤ S1	DF = 1.0	Eq. 18-19
Int.	2	10' ≥ S1 > 4'	S2 ≤ 6'	DF = 1.0 + (S1 - 4) / S1	Eq. 18-21
Int.	2	10' ≥ S1 > 4'	S1 ≥ S2 > 6'	DF = 1.0 + (S1 - 4') / S1 + (S2 - 6') / S2	Eq. 18-22
Int.	2	S1 > 10'	S2 ≤ 6'	DF = 1.0 + (2 * S1 - 14) / S1	Eq. 18-23
Int.	2	S1 > 10'	S1 ≥ S2 > 6'	DF = 1.0 + (2 * S1 - 14) / S1 + (S2 - 6') / S2	Eq. 18-24
Ext.	1	(S + OH) ≤ 6'	OH = 0	DF = 1.0	Eq. 18-19
Ext.	1	(S + OH) ≤ 6'	OH > 0	DF = (S1 + OH) / S1	Eq. 18-25
Ext.	1	(S + OH) > 6'	OH = 0	DF = 1.0 + (S1 - 6') / S1	Eq. 18-20
Ext.	1	(S + OH) > 6'	OH > 0	DF = 2 * (S1 + OH - 3') / S1	Eq. 18-26
Ext.	2	(S + OH) ≤ 6'	OH = 0	DF = 1.0	Eq. 18-19
Ext.	2	(S + OH) ≤ 6'	OH > 0	DF = (S + OH) / S	Eq. 18-25
Ext.	2	10' ≥ (S + OH) > 6'	OH = 0	DF = 1.0 + (S - 6') / S	Eq. 18-20
Ext.	2	10' ≥ (S + OH) > 6'	OH > 0	DF = 2 * (S + OH - 3') / S	Eq. 18-26
Ext.	2	16' ≥ (S + OH) > 10'	OH = 0	DF = 1.0 + (2 * S1 - 16') / S	Eq. 18-27
Ext.	2	16' ≥ (S + OH) > 10'	OH > 0	DF = 3 * (S + OH - 5.33) / S	Eq. 18-28
Ext.	2	(S + OH) > 16'	OH = 0	DF = 1.0 + (3 * S1 - 32') / S	Eq. 18-29
Ext.	2	(S + OH) > 16'	OH > 0	DF = 4 * (S + OH - 8') / S	Eq. 18-30

S1 = Larger Adjacent Pile Spacing for Interior Pile (FT)
S2 = Smaller Adjacent Pile Spacing for Interior Pile (FT)
S = Exterior Pile Spacing for Exterior Pile (FT)
OH = Wheel Line Overhang at Exterior Pile (FT)

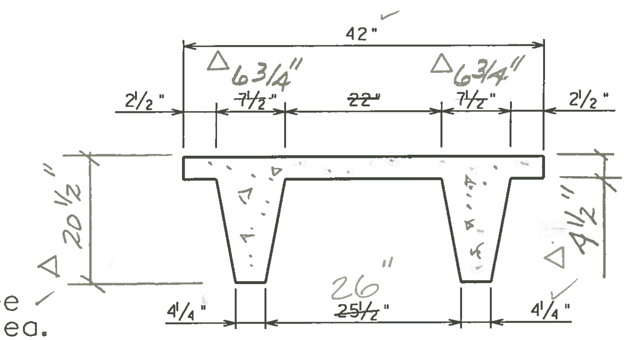
Figure 25: Pile Distribution Factors (Timber)



ELEVATION VIEW



TYPICAL SECTION



Concrete Double "T" Detail

Wt of Dbl. Tees
= ~~.109~~ ksf.
= 0.108 ksf
mw

Not to Scale

BRIDGE SKETCH **BRIDGE NO. AA0167-002**

ROAD CR 1170 (USFS Rd 511)

CREEK Sikes Creek

Texas Department of Transportation

TBLRP-LFR Spreadsheet

Timber Pile (ASD)

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Lufkin (11)	AADT ®:	50	# of Lanes:	1
County:	Houston (114)	Truck % (1% MIN):	1%		
Structure # :	AA01-67-002	EV Daily Crossing:	1	(1 or 10)	One Direction
Location:	CR 1170 Over Sikes Creek	Year Built:	1999		
		Pile Descr:	12" Diameter Timber Pile		

Deck Inputs

DATA INPUT TABLE	
Pile ID Number:	3
Interior or Exterior Pile:	Interior
Interior Pile Spacing - 1 (ft):	6.50
Interior Pile Spacing - 2 (ft):	6.50
Pile Height (ft):	12.00
Pile Diameter (in):	12.000
Section Loss (%):	10%
Pile Unit Weight (kcf):	0.050
Pile Condition	Good
Abutment or Int. Bent	Int. Bent
Adjacent Span Length 1 (ft):	35.00
Adjacent Span Length 2 (ft):	20.00
Effective Length "K" Factor:	1.00
Method for Subsurface Capacity:	Assumed Pile Capacity
Superstructure Material Type:	Concrete
Is Superstructure Continuous Over Pile:	No

IMPORT FROM CAP MODULE	
Cap Module:	No Import

DEAD LOAD CALCS	
Effective Deck Length for Dead Loads (ft):	27.50
Effective Tributary Deck Width for Dead Loads (ft):	6.50
Deck Type: Concrete Deck	
Deck+Fill+Wear. Surface (ksf):	0.056
Superstructure Type: Concrete Girder	
Superstructure Member Spacing (in):	21.000
Superstructure Member Weight (klf):	0.094
Cap Type: Timber Cap	
Cap Weight (klf):	0.059
Total Dead Load (ksf):	**0.112**
MISC. PILE ANALYSIS PROPERTIES*	
Wheel Line Distribution Factor, DF:	1.08
Timber Grade:	No. 1
Modulus of Elasticity, E (ksi):	1600.0
Allowable Compression Stress, F_c (ksi):	0.920
Subsurface Capacity, P_{ALL} (k):	48.0
Column Capacity, P_{ALL} (k):	101.0
Net Section, P_{ALL} (k):	93.6
Controlling F_C' (ksi):	0.893
Slenderness Ratio, kl/d:	15.28
Long Column Ratio, C:	27.98

***The Recommended values above shall be verified by the engineer and adjusted if necessary.*

Analysis

Compression Analysis	
Max H15 Reaction (k):	13.8
Max HS15 Reaction (k):	20.1
Pile Capacity, P_{ALL} (k):	48.0
P_{DL} (k):	20.0
[Max H15] - P_{LL} (k):	14.9
IR (H15):	28.3
IR (HS15):	19.4
OR (H15):	40.4
OR (HS15):	27.7

Additional Notes

Year, Bridge Condition, and Traffic Values assumed.

€ - Compression Controls Ratings
¥ - Based on H-20 Rating
£ - Compression Controls Ratings

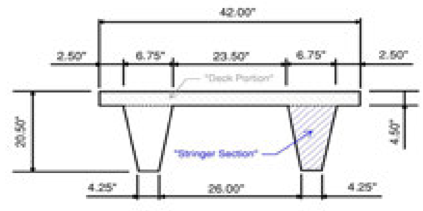
€ HS Ratings			
HS Inventory:	HS 19.4	RF= 0.97	
HS Operating:	HS 27.7	RF= 1.39	
¥£ H RATING			
H Inventory:	H 28.3	RF= 1.41	
H Operating:	H 40.4	RF= 2.02	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	1.50	TYPE 3:	1.76
SU_5 Operating:	1.42	TYPE 3S2:	1.74
SU_6 Operating:	1.28	TYPE 3-3:	1.84
SU_7 Operating:	1.20	NRL:	1.15
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	1.54	EV_3 Operating:	0.99

Values calculated based on Allowable Stress Method

*** DO NOT DISCLOSE ***
THIS INFORMATION IS CONFIDENTIAL UNDER THE TEXAS HOMELAND SECURITY ACT AND 23 USC SECTION 409, SAFETY SENSITIVE INFORMATION

Timber Pile

Inputs



Reference visual above for Dead Load Inputs

Interior or Exterior Pile:	Interior
Interior Pile Spacing - 1:	6.50 ft
Interior Pile Spacing - 2:	6.50 ft
Pile Height:	12.00 ft
Pile Diameter:	12.000 in
Section Loss:	10 %
Pile Unit Weight:	0.050 kcf
Pile Condition	Good
Timber Grade:	No. 1
Abutment or Int. Bent	Int. Bent
Adjacent Span Length 1:	35.00 ft
Adjacent Span Length 2:	20.00 ft
Effective Length "K" Factor:	1.00
Modulus of Elasticity, E (ksi):	1600.0
Method for Subsurface Capacity:	Assumed Pile Capacity
Subsurface Capacity, P_{ALL} (k):	48.0
Superstructure Material Type:	Concrete
Is Superstructure Continuous Over Pile:	No
Allowable Compression Stress, F_c (ksi):	0.920

Concrete Tee Beam (Deck Portion) Thickness:	4.500 in
Deck+Fill+Wear. Surface:	0.056 ksf
*Calc = [(4.5 in / 12 in * 1 ft) * 0.150 kcf]*	
Superstructure Member Spacing:	21.000 in
Calc = (42.000 in / 2 Stringer Sections)	
Superstructure Member Weight:	0.094 klf
*Calc = ([(4.50 in * 16 in) + (2 * 16.0 in * 1.125 in/2)] / 144 in^2 * 1 ft^2) * 0.150 kcf*	

Additional Properties Used in Analysis

Effective Deck Length for Dead Loads (ft) =	(35.00 ft + 20.00 ft) / 2	=	27.50 ft
Effective Tributary Deck Width for Dead Loads (ft) =	(Int. Pile Spacing - 1 (ft) + Int. Pile Spacing - 2 (ft)2) / 2		
Effective Tributary Deck Width for Dead Loads (ft) =	(6.50 ft + 6.50 ft) / 2	=	6.5 ft

Dead Loads

Deck (k/ft^2) =	[(4.500 in * (1 ft / 12 in)) * 0.150 kcf]	=	0.056 ksf
(Longitudinal Loading) Stringers (k/ft) =	[(4.500 in * 16 in) + (2 * 16.0 in * 1.125 in / 2)] * (1 ft^2/ 144 in^2) * 0.150 kcf	=	0.094 klf
(Transverse Loading) Stringers (k/ft^2) =	0.094 k/ft / (21.000 in * (1 ft / 12 in))	=	0.054 ksf
Timber Cap (k/ft) =	(13.000 in) * (13.000 in) * (1 ft^2 / 144 in^2) * 0.050 kcf	=	0.059 klf
Timber Cap (k/ft^2) =	0.059 k/ft / (Effective Deck Length for Dead Loads) = 0.059 k/ft / 27.50 ft	=	0.002 ksf
Total Dead Load, TDL =	Deck Wt. (ksf) + (Trans. Loading) Stringers Wt. (ksf) + Timber Cap Wt. (ksf)	=	0.112 ksf

Note: Values above are rounded (not all decimals shown).

Timber Pile

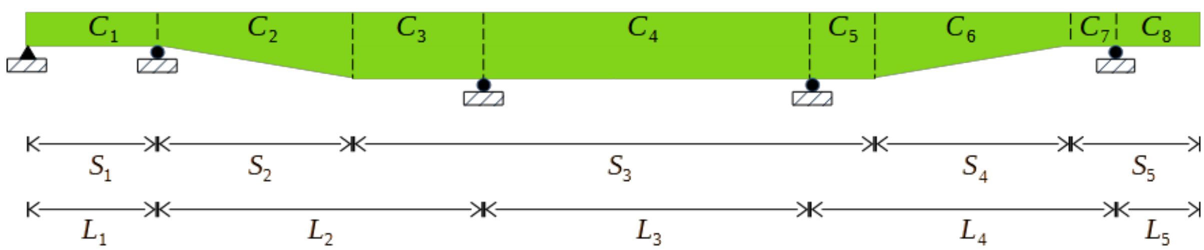
Compression Analysis Calculations

Pile Area, AG (in^2) =	$(12.000\ in)^2 * \pi / 4$	=	113.09 in^2
Slenderness Ratio =	(K factor) * (Pile Height (in) / (Pile Diameter * π / 4)		
Slenderness Ratio =	1.00 * [12.00 ft * (12 in / 1 ft)] / [12.000 in * π / 4]	=	15.28
Long Column Ratio, C =	(0.671)*(Modulus of Elasticity/Allowable Compression Stress)$^{(1/2)}$		
Long Column Ratio, C =	(0.671)*(1600 ksi / 0.920 ksi)$^{(1/2)}$	=	27.98
F_c' (Scenario 1) =	Allowable Compresssion Stress, F_c (ksi)	=	0.920 ksi
Note: Use Scenario 1 when kl/d is less than or equal to 11.000			
F_c' (Scenario 2) =	Fc (ksi) * (1 - 0.33 * [Slenderness Ratio / Long Column Ratio]^4)		
F_c' (Scenario 2) =	0.920 ksi * (1 - 0.33 * [15.28 / 27.98]^4)	=	**0.893 ksi**
Note: Use Scenario 2 when kl/d is greater than 11.000 and less than the Long Column Ratio of 27.983			
F_c' (Scenario 3) =	0.3 * Modulus of Elasticity (ksi) / (Slenderness Ratio)^2 = 0.3 * 1600.0 ksi / (15.28)^2	=	2.056 ksi
Note: Use Scenario 3 when kl/d is greater than or equal to the Long Column Ratio of 27.983			
P_{ALL} [Column Capacity]=	Pile Area, AG (in^2) * F_c' (ksi) = 113.09 in^2 * 0.893 ksi	=	101.0 k
P_{ALL} [Subsurface Capacity]=	4 k / in * Timber Pile Diameter (in) = 4 k / in * 12.000 in	=	48.0 k<<<
Note: If P_{ALL} Subsurface Capacity is unknown, 4 kips per inch of pile diameter is reasonable starting assumption.			
P_{ALL} [Net Section Capacity]=	Pile Area, AG (in^2) * Allow. Comp. Stress, F_c (ksi) * (100% - Section Loss %)		
P_{ALL} [Net Section Capacity]=	113.09 in^2 * 0.920 ksi * (100% - 10%)	=	93.6 k
	P_{ALL} based upon the minimum of the 3 calculations above	=	48.0 k
P_{DL} =	TDL (ksf) * Eff. Trib. Deck Width for Dead Loads (ft) * Eff. Deck Length for Dead Loads(ft)		
P_{DL} =	0.112 (ksf) * 6.50 (ft) * 27.50 (ft)	=	20.0 k
	LL Distribution Factor Calcs (Interior Pile, 1-Lane):		
	Pile Spacing 1 > 6.00 ft		
	Pile Spacing 2 ≤ Pile Spacing 1		
	Reference Pile Distribution Factors Table based upon the criteria above		
LLDF =	1 + (Pile Spacing ft - 6.00 ft) / Pile Spacing ft = 1+(6.50 ft - 6.00 ft) / (6.50 ft)	=	1.08
H15 Wheel Line React. (k) =	(12 k + 3 k * (Largest Span ft -14 ft) / (Largest Span ft))	=	13.8 k
H15 Wheel Line reaction (k) =	(12 k + 3 k * (35.00 ft -14 ft)/(35.00 ft))	=	
HS15 Wheel Line reaction (k) =	[12 k * (2 k * Lrg. Sp. ft -14 ft) / (Lrg. Sp. ft)] + [3k * (Small Sp. ft - 14 ft) / (Small Sp. ft)]		
HS15 Wheel Line reaction (k) =	[12 k * (2 k * 35.00 ft -14 ft) / (35.00 ft)] + [3k * (20.00 ft - 14 ft) / (20.00 ft)]	=	20.1 k
H15 P_{LL} =	H15 Reaction x LLDF = (13.8 k) * (1.08)	=	14.9 k
HS15 P_{LL} =	HS15 Reaction x LLDF = (20.1 k) * (1.08)	=	21.6 k
Inventory H Rating =	15 * ((48.0 k - 20.0 k) / (14.9 k)	=	**H 28.3 <<<**
Operating H Rating =	15 * ((1.25 * 48.0 k - 20.0 k) / (14.9 k)	=	**H 40.4 <<<**
Inventory HS Rating =	15 * ((48.0 k - 20.0 k) / (21.6 k)	=	**HS 19.4 <<<**
Operating HS Rating =	15 * ((1.25 * 48.0 k - 20.0 k) / (21.6 k)	=	**HS 27.7 <<<**

Note: Values above are rounded (not all decimals shown).

Section 19: Steel Flatcar

The typical flatcar considered for this load rating module consists of five segments, the two shallow segments at both ends, the two tapered segments at both ends and the deeper segment in the middle. In some scenarios, this flatcar configuration may be cut in half, resulting in three segments of analysis (one shallow segment, one tapered segment, and one deeper segment). In *Figure 26: Typical Flatcar Model* below, the support locations and flatcar segment geometry are both considered to develop "components", which are the portions of the flatcar broken out for analysis within the module.



S_i: Segment Length (ft)

L_i: Span Length (ft)

C_i: Component Number

Figure 26: Typical Flatcar Model

Note: The component locations shown above are not entered by the user. They are calculated based upon the segment geometry and span geometry.

Note: The typical model above shows one cantilevered span at the end (right) of the structure. However, spans can be cantilevered at the start (left) and end (right) of the structure within the software.

1. **DECK INPUTS**
    a. ***Import Values from Defined Deck Module*** – Select a deck module from the drop-down list to import previously input deck dead load info.
        i. The deck modules that aren't in use will not be displayed in the drop-down list.
        ii. Select 'No Deck Import' to define a new deck and dead loads.
        iii. Deck modules that are not completely filled out may not import the desired loads.
    b. ***Deck Type*** – Select the Deck Type to use for the analysis.
        i. This is automatically filled in when values are imported. This cell is available to edit if 'No Deck Import' is selected.
        ii. Deck Type Options:
            1. 'Concrete Deck'
                a. Composite nature is not considered in this module.
            2. 'Steel Corrugated Deck'
            3. 'Steel Plate Deck'

        4. 'Steel Open Grid Deck'
        5. 'Timber Deck'
    c. ***Deck Designation [Steel Corrugated Deck, Steel Open Grid Deck only]*** – Select the deck designation from the drop down. This will calculate the Deck Weight field.
        i. If the desired deck designation is not in the drop-down, type in the designation name and the Deck Weight input will have to be manually calculated.
    d. ***Deck Thickness (in) [Concrete Deck, Steel Plate Deck, Timber Deck only]*** – Input the deck thickness.
        i. ***Deck weight (ksf)*** below will automatically calculate based upon the standard material unit weights of the selected deck type.
    e. ***Deck Weight (ksf)*** – Value imported from deck module or calculated based on deck thickness input.
        i. This cell can be overwritten at the Engineer's discretion.
    f. ***Fill Weight (ksf)*** - Input the weight of fill acting on the deck.
    g. ***Wearing Surface Weight (ksf)*** – Input the weight of wearing surface acting on the deck.
    h. ***Misc. Loads (ksf)*** – Input any additional deck dead loads to be included.
2. **LIVE LOAD FACTORS**
    a. ***Deck Type for LLDF*** – Select the deck type to calculate the corresponding live load distribution factors (LLDF). In most cases, it will match the deck type.
        i. For Steel Open Grid Decks and Nail/Glue Laminated Timber decks, the deck thickness is needed for the LLDF.
    b. ***LLDF Table*** – This table shows the calculated LLDFs (*AASHTO Table 3.23.1*) and the Impact Factor (IM) calculated as 1 + (50 / (Length + 125)) < 1.3. An override column is provided for each span for use at the Engineer's discretion.
        i. The live load distribution factors that are auto-calculated are based upon an interior member analysis.
            1. This value defaults to 2.0 when "Yes" is selected in the Analyze 1 Truck per Flatcar input below.
3. **DATA INPUT TABLE**
   Note: Some of the flatcars within TxDOT's inventory have soil bearings at one or both ends of the structure behind the abutments. When erosion occurs at these locations, analysis may be required for an additional continuous span. In the instance the erosion causes an unstable soil bearing, a cantilever span analysis may be warranted by the engineer of record. In this scenario, select "Yes" for the cantilever span options below depending on the location. See *Figure 27: Scenario – Span Analysis Examples* for reference.

    a. ***Number of Spans -*** Select between 1 and 5 spans for the structure.
        i. If 1 span is selected, the module will analyze the structure for positive moments only.
        ii. If more than 2 spans are selected, continuous analysis will be performed on the structure (positive and negative moments).
    b. ***Is First Span a Cantilever:*** Select "Yes" if the first span is cantilevered. Select "No" if the first span is not cantilevered.
        i. When 1 span is selected above, this cell defaults to "No".
        ii. The first span is the leftmost span in the analysis.

c. ***Is Last Span a Cantilever:*** Select "Yes" if the last span is cantilevered. Select "No" if the last span is not cantilevered.
    i. When 1 span is selected above, this cell defaults to "No".
    ii. The last span is the rightmost span in the analysis.
d. ***CL-CL Flatcar Spacing (For LLDF) (ft)*** – Input the centerline to centerline spacing between adjacent flatcar segments.
    i. When there is only one flatcar being analyzed, input the roadway width.
    ii. This cell is used to calculate the LLDF value in the table above.
e. ***Analyze 1 Truck per Flatcar*** – Select yes to set the LLDF to 2.
    i. This should be used when the user decides to analyze the flatcar with a single truck loading (2 wheel lines per flatcar).
f. ***Flatcar Width (for Dead Loads) (ft) –*** Input the width of the flatcar to be considered for deck dead loads.
    i. If only 1 flatcar unit is acting as the longitudinal member for the structure, input the overall deck width.
g. ***Span Length (ft) –*** Input the length of each span.
    i. Reference *Figure 26: Typical Flatcar Model* for a visual representation on how to input span lengths.

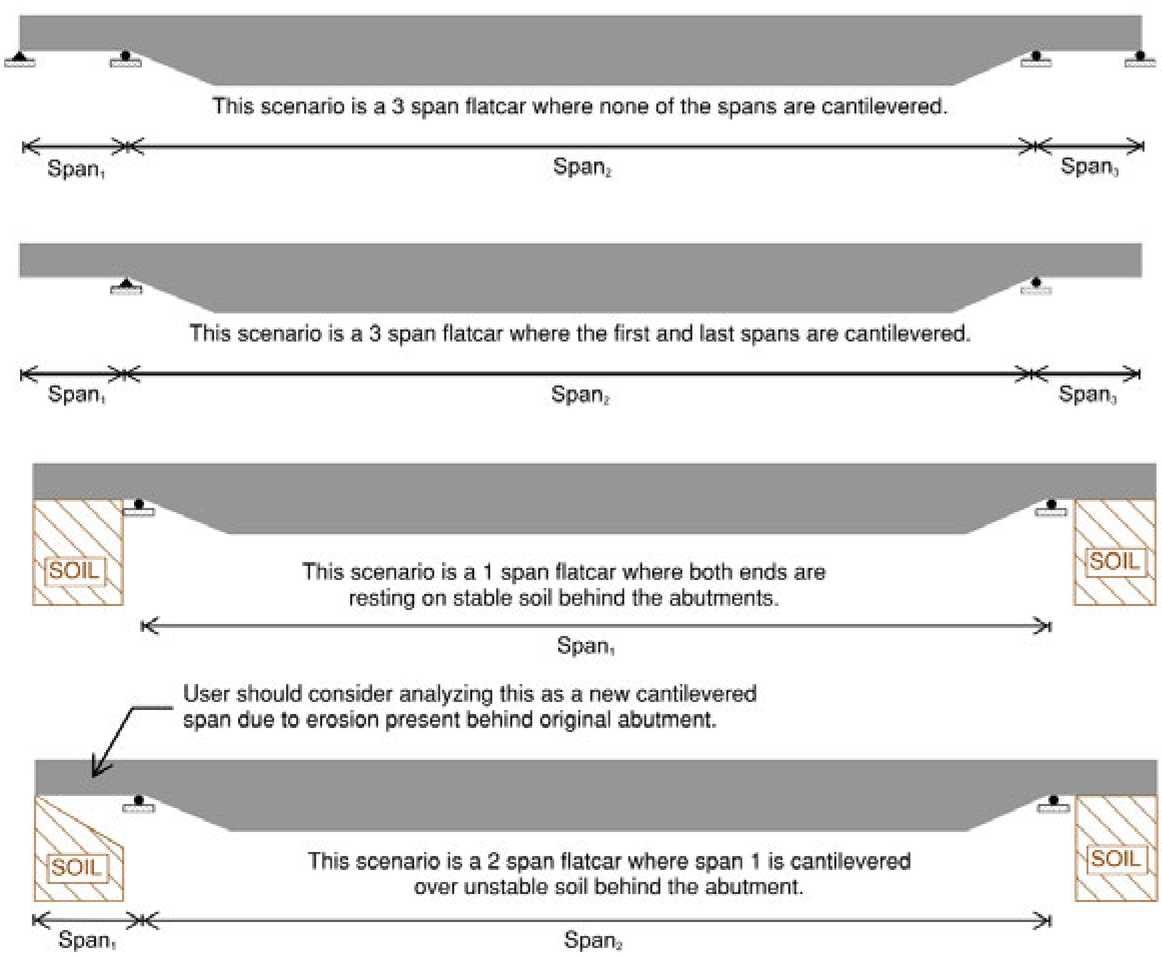


Figure 27: Scenario – Span Analysis Examples

4. **FLATCAR INPUT TABLE**

Note: The user can access the Flatcar Properties Calculator on pages 3 and 4 of the module to calculate the start and end section modulus, weight, and moment of inertia. Refer to *Figure 29: Flatcar Properties Printings Adjustments* and *Figure 30: Flatcar Properties Calculator Input Options* for additional information.

a. ***Number of Segments –*** Select between 1 and 5 segments to be load rated.
    i. Refer to *Figure 28: Flatcar Segments* for additional information.
b. ***F_y (ksi) –*** Input the yield stress of the flatcar. If unknown, this value is recommended based upon the date built, as seen in *Appendix A.*
c. ***Segment Length (ft) –*** Input the length of each segment of Flatcar.
    i. Reference *Figure 26: Typical Flatcar Model* for a visual representation on how to input segment lengths.
    ii. Refer to *Figure 28: Flatcar Segments* for additional information.
d. ***Start Moment of Inertia (in^4) –*** Input the moment of inertia at the start of the segment.
e. ***Start $S_{x\text{-}Bot}$ (in^3) –*** Input the starting section modulus for the bottommost fiber of the segment to the neutral axis.
f. ***Start $S_{x\text{-}Top}$ (in^3) –*** Input the starting section modulus for the topmost fiber of the segment to the neutral axis.
g. ***Start $W_{Segment}$ (k/ft) –*** Input the weight of the flatcar at the start of the defined segment.
    i. This should be the weight at the left end of the defined segment.
    ii. When multiple segments are used to make up a flatcar member, the starting segment weights after segment 1 will reference the ending segment weight of the prior segment.
h. ***End Moment of Inertia (in^4) –*** Input the moment of inertia at the end of the segment.
i. ***End $S_{x\text{-}Bot}$ (in^3) –*** Input the end section modulus for the bottommost fiber of the segment to the neutral axis.
j. ***End $S_{x\text{-}Top}$ (in^3) –*** Input the end section modulus for the topmost fiber of the segment to the neutral axis.
k. ***End $W_{Segment}$ (k/ft) –*** Input the weight of the flatcar at the end of the defined segment.
    i. This should be the weight at the right end of the defined segment.
l. ***Misc. Dead Load per Segment (k/ft) –*** Input any additional dead loads per each flatcar segment.
    i. These additional loads should be any attachments to the flatcar segment that are not considered in the section modulus and moment of inertia calculations, such as bracing or connection plates.
    ii. These could also be any additional loads not defined in the deck for the dead loads that need to be considered.

Figure 28: Flatcar Segments

5. FLATCAR PROPERTIES CALCULATOR

When using the Steel Flatcar module, users will potentially need to calculate new or updated section properties for the Flatcar Segment(s) in order to input the necessary information on Page 1 of the module. The Flatcar Properties page(s) are available within the module to assist with these calculations. The 2 pages provide 4 different segment calculators to help with calculating the flatcar segments' moment of inertias, section modulus's (from the top and bottom fibers), and weights. The user needs to input the various sections, plates, and members that make up the analyzed flatcar, with the combined totals shown underneath each table. An example of two different approaches to input steel sections for the same flatcar segment into the calculator is presented in *Figure 30: Flatcar Properties Calculator Input Options*.

These extra 2 pages do not need to be printed or used in all load rating scenarios. These two pages are optional, and not necessary for the user to run analysis. If the user does not want one or two of these pages to be printed, they can click the buttons provided at the top of the first Flatcar Properties page, as shown in *Figure 29: Flatcar Properties Printings Adjustments* below:

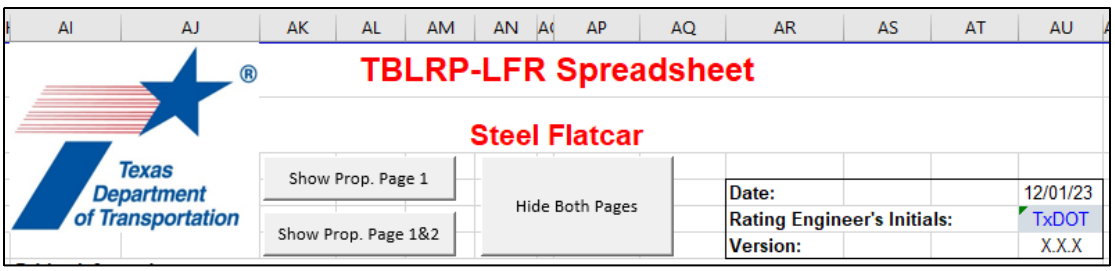


Figure 29: Flatcar Properties Printings Adjustments

a. ***Flatcar Segment Description*** – Input the description of the flatcar segment (Ex. North Flatcar Deep Section).
b. ***Total Depth of Flatcar Segment (in)*** – Input the depth of the flatcar segment.
    i. Many flatcars vary in depth, so evaluating the deeper and shallower section is typically necessary to generate the correct section modulus values across the structure.
c. ***Plate Section(s) [Rectangular]*** – Input each rectangular plate section type that makes up the overall flatcar segment. This section can also be used to input a more complicated steel section that has been broken up into rectangular steel sections.
    i. ***# of Sections*** – Input the quantity of each plate section.
    ii. ***b (in)*** – Input the dimension of the base of the section.
    iii. ***h (in)*** – Input the dimension of the height of the section.
    iv. ***$A_{individual}$ (in^2)*** – Input the area of the individual plate section. This can be calculated by multiplying b*h.
        1. This cell is auto-calculated by the spreadsheet based upon b(in) and h (in) inputs.
    v. ***A_{total} (in^2)*** – This is the total area of the steel section(s) being used for analysis.
        1. This cell is auto-calculated by the spreadsheet based upon the number of sections and the section's individual area value.

vi. ***Y (in)*** – Input the distance of the neutral axis of each section to the bottommost fiber of the overall flatcar segment.
   1. See *Figure 30: Flatcar Properties Calculator Input Options* for additional information.

vii. ***A_{Total}*Y (in^3)*** – This cell is auto-calculated by multiplying the A_{total} by the Y value.

viii. ***$I_{individual}$ (in^4)*** – Moment of inertia of the individual section. This can be computed using the formula $b*h^3/12$.
   1. This cell is auto-calculated by the spreadsheet based upon b(in) and h (in) inputs.

ix. ***I_{total} (in^4)*** – This cell is auto-calculated by multiplying the $I_{individual}$ by the # of Sections.

x. ***$A*(y_b\text{-}Y)^2$ –*** This cell is auto-calculated by multiplying A_{Total} by $(y_b\text{-}Y)^2$.

d. ***Rolled Section(s) [Non-Rectangular]*** – Input each rolled and/or non-rectangular section that makes up the overall flatcar segment.

   i. ***# of Sections*** – Input the quantity of each rolled section.

   ii. ***$A_{individual}$ (in^2)*** – Input the area of the individual rolled section.
      1. This value will need to be calculated by the user or pulled from a standard steel shape database.

   iii. ***A_{total} (in^2)*** – This is the total area of the steel section(s) being used for analysis.
      1. This cell is auto-calculated by the spreadsheet based upon the number of sections and the section's individual area value.

   iv. ***Y (in)*** – Input the distance of the neutral axis of each section to the bottommost fiber of the overall flatcar segment.
      1. See *Figure 30: Flatcar Properties Calculator Input Options* for additional information.

   v. ***A_{Total}*Y (in^3)*** – This cell is auto-calculated by multiplying the A_{total} by the Y value.

   vi. ***$I_{individual}$ (in^4)*** – Input the moment of inertia for the individual section.

   vii. ***I_{total} (in^4)*** – This cell is auto-calculated by multiplying the $I_{individual}$ by the # of Sections.

   viii. ***$A*(y_b\text{-}Y)^2$ –*** This cell is auto-calculated by multiplying A_{Total} by $(y_b\text{-}Y)^2$.

e. **I_x –** The moment of inertia is calculated for the entire segment of flatcar based upon the input sections above.

f. ***$W_{segment}$* –** The weight is calculated for the entire segment of flatcar based upon the input sections above.

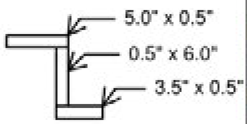
g. ***Y_{Bot}* –** Calculated distance to the centroid of the combined sections from the bottommost fiber of the flatcar segment.

h. ***$S_{x\text{-}Bot}$*** **-** Section modulus calculated for the top-most fiber of the segment to the neutral axis.

i. ***Y_{Top}*** **-** Calculated distance to the centroid of the combined sections from the topmost fiber of the flatcar segment.

j. ***$S_{x\text{-}Bot}$*** **-** Section modulus calculated for the topmost fiber of the segment to the neutral axis.

Flatcar Properties Calculator



Option 1:
(input as plate / rectangular sections)

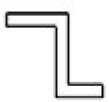
Flatcar Segment Description: South Flatcar (Shallow Section) Total Depth of Flatcar Segment (in): 13.000 in

Plate Section(s) [Rectangular]	# of Sections	b [in]	h [in]	$A_{individual}$ [in^2]	A_{total} [in^2]	Y [in]	A_{total}*Y [in^3]	$I_{individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
12" x 0.75" Side Plate	2	0.750	12.000	9.000	18.000	7.000	126.000	108.00	216.00	13.792
1" x 24" Bottom Plate	1	24.000	1.000	24.000	24.000	0.500	12.000	2.00	2.00	759.284
Unknown Shape 0.5" x 5.0" Top	2	5.000	0.500	2.500	5.000	12.750	63.750	0.05	0.10	219.476
Unknown Shape 0.5" x 5.0" Middle	2	0.500	6.000	3.000	6.000	9.500	57.000	9.00	18.00	68.357
Unknown Shape 0.5" x 5.0" Bot	2	3.500	0.500	1.750	3.500	6.250	21.875	0.04	0.07	0.055
Rolled Section(s) [Non-Rectangular]	# of Sections	-	-	$A_{individual}$ [in^2]	A_{total} [in^2]	Y [in]	A_{total}*Y [in^3]	$I_{individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
W12 x 45	2	-	-	13.100	26.200	7.000	183.400	348.00	696.00	20.075
C8 x 11.5	2	-	-	3.370	6.740	12.428	83.765	1.31	2.62	267.794
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
				Σ =	89.44 in^2	Σ =	547.8 in^3	Σ =	935 in^4	1349 in^4
									+	935 in^4
									I_x =	2284 in^4

$W_{Segment}$ = ΣA*0.49/144 = 0.304 kip/ft

y_{Bot} = ΣA*y/ΣA = 6.125 in
$S_{x,Bot}$ = I_x/y_{Bot} = **372.858 in^3**
y_{Top} = Depth - y_{Bot} = 6.875 in
$S_{x,Top}$ = I_x/y_{Top} = **332.148 in^3**

Flatcar Properties Calculator



Option 2:
(input as a rolled / non-rectangular section)

Flatcar Segment Description: South Flatcar (Shallow Section) Total Depth of Flatcar Segment (in): 13.000 in

Plate Section(s) [Rectangular]	# of Sections	b [in]	h [in]	$A_{individual}$ [in^2]	A_{total} [in^2]	Y [in]	A_{total}*Y [in^3]	$I_{individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
12" x 0.75" Side Plate	2	0.750	12.000	9.000	18.000	7.000	126.000	108.00	216.00	13.792
1" x 24" Bottom Plate	1	24.000	1.000	24.000	24.000	0.500	12.000	2.00	2.00	759.284
				0.000	0.000		0.000	0.00	0.00	0.000
				0.000	0.000		0.000	0.00	0.00	0.000
				0.000	0.000		0.000	0.00	0.00	0.000
Rolled Section(s) [Non-Rectangular]	# of Sections	-	-	$A_{individual}$ [in^2]	A_{total} [in^2]	Y [in]	A_{total}*Y [in^3]	$I_{individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
W12 x 45	2	-	-	13.100	26.200	7.000	183.400	348.00	696.00	20.075
C8 x 11.5	2	-	-	3.370	6.740	12.428	83.765	1.31	2.62	267.794
0.5" unknown rolled shape	2	-	-	7.250	14.500	9.836	142.625	53.16	106.32	199.746
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
				Σ =	89.44 in^2	Σ =	547.8 in^3	Σ =	1023 in^4	1261 in^4
									+	1023 in^4
									I_x =	2284 in^4

$W_{Segment}$ = ΣA*0.49/144 = 0.304 kip/ft

y_{Bot} = ΣA*y/ΣA = 6.125 in
$S_{x,Bot}$ = I_x/y_{Bot} = **372.858 in^3**
y_{Top} = Depth - y_{Bot} = 6.875 in
$S_{x,Top}$ = I_x/y_{Top} = **332.148 in^3**

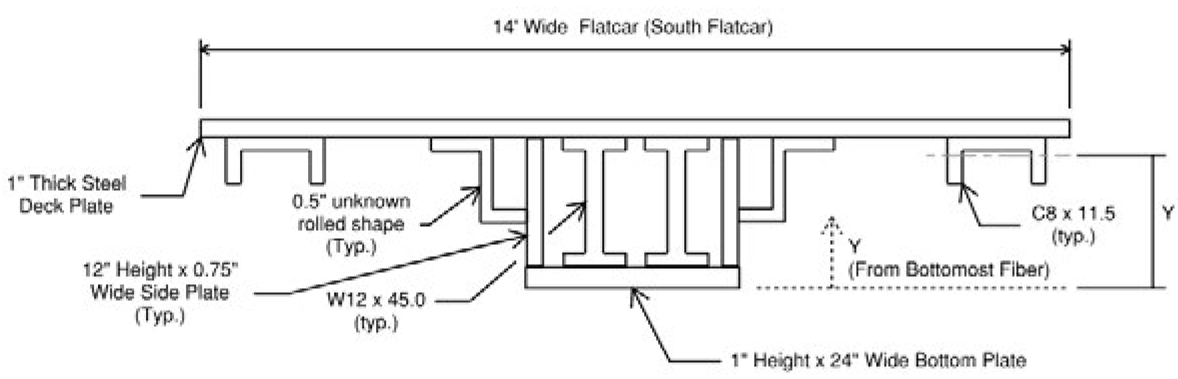


Figure 30: Flatcar Properties Calculator Input Options

6. **RUN FLATCAR ANALYSIS**

   Push the ‘Run Flatcar Analysis’ button when all information in Deck Inputs, Live Load Factors, Data Input Table, and Flatcar Input Table have been input. Validation checks will run to ensure data was input correctly and a message box will notify the user of critical errors.

7. **ANALYSIS**

   The analysis of the flatcar follows that for a continuous span system, even when the flatcar may be modeled as a single span, simply supported beam. In this analysis, the continuity is defined by the change in the cross-section geometry of the segments in the flatcar model.

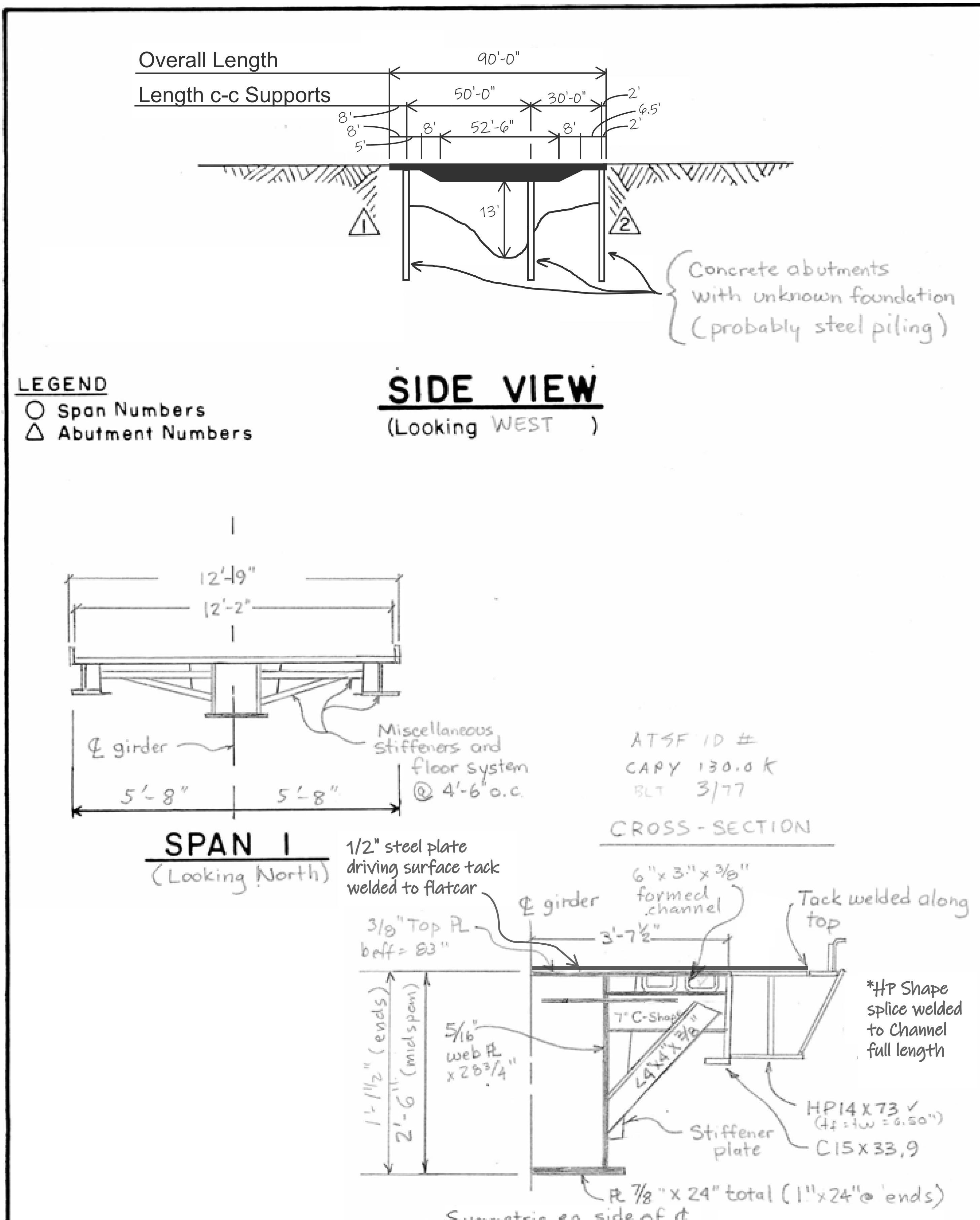
   The calculation of the influence lines for the flatcar follows the same approach used for the continuous systems. That is, each component is divided into ten sections and the influence line values for each section is calculated following the Muller-Breslau method as seen in *Appendix F*. Once these values are calculated for each section in all segments, the analysis trucks’ geometries and weights are used to calculate the maximum bending moments at each section. These values then are adjusted by the distribution factors.

   a. ***Controlling Truck Moments (Positive / Negative)***
      i. The table(s) on page 2 of the module show the controlling locations within the span and segment that dictate the ratings and rating factors seen in the summary table at the bottom of page 1.
      ii. Two tables are present, one for the controlling positive moment analysis values and one for the controlling negative moment analysis values.
         1. When a single span is used, the Controlling Truck Moments (Negative) table is hidden since no negative moments are induced on the structure.
      iii. ***Capacity (k-ft)*** - Presents the calculated controlling moment capacity for the flatcar segment at the location identified for each respective truck. The capacity is determined to be (+/-) based on the M_{LL} present at that location.
      iv. **DL (k-ft)** - Presents the calculated dead load moment for controlling location along the flatcar segment for each respective truck.
      v. **LL (k-ft)** - Presents the calculated dead load moment for controlling location along the flatcar segment for each respective truck.

General Notes:

- Changing certain inputs on page 1 of the Flatcar module can cause the analysis results to delete. When these cells are edited, the analysis resets and will then need to be re-run.
- Full analysis results are shown in the table located in cell AY92. Values are in k-in.
- Additional analysis information can be found in the table located in cell BP90.
- Rating factor calculations are shown in the table located in cell CC90 for each truck.
- The support locations used in the analysis are calculated based upon the defined span lengths and cantilevered span locations, with reference to the left end of the structure.

Below sketch for example purposes only.



TBLRP-LFR Spreadsheet

Steel Flatcar

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District:	Tyler (10)	**AADT ®:**	35	**# of Lanes:**	1
County:	Anderson (001)	**Truck % (1% MIN):**	1%		
Structure # :	CCCC-SS-SSS	**EV Daily Crossing:**	1	**(1 or 10)** One Direction	
Bridge Description	Roadway Over Stream	**Year Built:**	1995		
		Railcar Descr:	3 Span Flatcar		

Input Tables

DECK INPUTS	
Import Values from Defined Deck Module:	No Deck Import
Deck Type:	Steel Plate Deck
Deck Thickness (in):	0.500
Deck Weight (ksf):	0.020
Fill Weight (ksf):	
Wearing Surface Weight (ksf):	
Misc. Loads (ksf):	

LIVE LOAD FACTORS					
Deck Type for Live Loads:	Steel Plate Deck				
	LLDF S/	LLDF	Override#	IM	Override#
Cant. 1:	-	2.00		1.30	
Span 2:	-	2.00		1.29	
Span 3:	-	2.00		1.30	

#Live load factor override columns will override the calculated values

DATA INPUT TABLE				
Number of Spans:	3	CL-CL Flatcar Spacing (For LLDF) (ft):	12.17	
Is First Span a Cantilever:	Yes	Analyze 1 Truck per Flatcar?	Yes	
Is Last Span a Cantilever:	No	Flatcar Width (for Dead Loads) (ft):	12.75	
Span ID:	**Cantilever 1**	**Span 2**	**Span 3**	
Span Length (ft):	8.00	50.00	30.00	

FLATCAR INPUT TABLE					
Number of Segments:	5	F_y (ksi):	36.0		
	Segment 1	**Segment 2**	**Segment 3**	**Segment 4**	**Segment 5**
Segment Length (ft):	13.00	8.00	52.50	8.00	6.50
Start Moment of Inertia (in^4):	4453.0	4453.0	15329.0	15329.0	4453.0
Start $S_{x\text{-}Bot}$ (in^3):	505.8	505.8	767.6	767.6	505.8
Start $S_{x\text{-}Top}$ (in^3):	718.6	718.6	1528.6	1528.6	718.6
Start $W_{Segment}$ (k/ft):	0.427	0.427	0.452	0.452	0.427
End Moment of Inertia (in^4):	4453.0	15329.0	15329.0	4453.0	4453.0
End $S_{x\text{-}Bot}$ (in^3):	505.8	767.6	767.6	505.8	505.8
End $S_{x\text{-}Top}$ (in^3):	718.6	1528.6	1528.6	718.6	718.6
End $W_{Segment}$ (k/ft):	0.427	0.452	0.452	0.427	0.427
Misc. Dead Load per Segment (k/ft):	0.100	0.100	0.100	0.100	0.100

Additional Notes

0.100 k/ft assumed for Misc. Dead Load per Segment to account for secondary steel members.

€ - Strength Controls Ratings
¥ - Based on H-20 Rating
£ - Strength Controls Ratings

€ HS Ratings			
HS Inventory:	HS 31.5	RF= 1.57	
HS Operating:	HS 52.6	RF= 2.63	
¥£ H Ratings			
H Inventory:	H 42.7	RF= 2.13	
H Operating:	H 71.2	RF= 3.56	
AASHTO LEGAL LOADS RATING FACTORS			
SU_4 Operating:	2.97	**TYPE 3:**	3.42
SU_5 Operating:	2.74	**TYPE 3S2:**	3.64
SU_6 Operating:	2.48	**TYPE 3-3:**	4.25
SU_7 Operating:	2.32	**NRL:**	2.28
EMERGENCY VEHICLE (EV) RATING FACTORS			
EV_2 Operating:	2.95	**EV_3 Operating:**	1.93

See Formula 6-1a (MCEB) for the general Rating Formula.

TBLRP-LFR Spreadsheet

Steel Flatcar

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District: Tyler (10)
County: Anderson (001)
Structure # : CCCC-SS-SSS
Bridge Description Roadway Over Stream

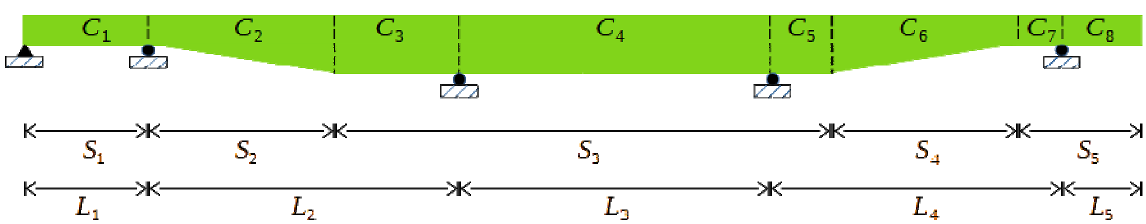
AADT ®: 35 **# of Lanes:** 1
Truck % (1% MIN): 1%
EV Daily Crossing: 1 **(1 or 10)** One Direction
Year Built: 1995
Railcar Descr: 3 Span Flatcar

Analysis

Controlling Moments (Positive)								
	Span	% span	Flatcar Segment	Segment %	Capacity (k-ft)	DL (k-ft)	LL (k-ft)	
H	3	78%	5	0%	1517.4	19.9	123.9	<<<
HS	2	41%	3	14%	2302.8	151.9	239.7	<<<
SU_4	2	41%	3	14%	2302.8	151.9	211.8	<<<
SU_5	2	41%	3	14%	2302.8	151.9	229.9	<<<
SU_6	2	41%	3	14%	2302.8	151.9	253.6	<<<
SU_7	2	41%	3	14%	2302.8	151.9	271.0	<<<
EV2	2	41%	3	14%	2302.8	151.9	326.1	<<<
EV3	2	41%	3	14%	2302.8	151.9	213.3	<<<
T3	2	41%	3	14%	2302.8	151.9	184.4	<<<
T3S2	2	41%	3	14%	2302.8	151.9	173.1	<<<
T3-3	2	48%	3	21%	2302.8	148.0	148.4	<<<
NRL	2	41%	3	14%	2302.8	151.9	276.4	<<<

Controlling Moments (Negative)							
	Span	% span	Flatcar Segment	Segment %	Capacity (k-ft)	DL (k-ft)	LL (k-ft)
H	2	0%	1	62%	2155.8	-25.2	-112.0
HS	2	0%	1	62%	2155.8	-25.2	-112.0
SU4	2	0%	1	62%	2155.8	-25.2	-85.0
SU5	2	0%	1	62%	2155.8	-25.2	-85.0
SU6	3	0%	3	70%	4585.8	-190.5	-184.2
SU7	3	0%	3	70%	4585.8	-190.5	-200.7
EV2	2	0%	1	62%	2155.8	-25.2	-155.0
EV3	2	0%	1	62%	2155.8	-25.2	-117.3
T3	2	0%	1	62%	2155.8	-25.2	-85.0
T3S2	2	0%	1	62%	2155.8	-25.2	-77.5
T3-3	3	0%	3	70%	4585.8	-190.5	-147.7
NRL	3	0%	3	70%	4585.8	-190.5	-204.6

Flatcar Inputs Visual:



C = Component (of Flatcar Analysis)
S = Segment Length (ft)
L = Span Length (ft)

*** DO NOT DISCLOSE ***
THIS INFORMATION IS CONFIDENTIAL UNDER THE TEXAS HOMELAND SECURITY ACT AND 23 USC SECTION 409, SAFETY SENSITIVE INFORMATION

TBLRP-LFR Spreadsheet

Steel Flatcar

Date:	05/24/24
Rating Engineer's Initials:	TxDOT
Version:	X.X.X

Bridge Information

District: Tyler (10)	**AADT ®:** 35 **# of Lanes:** 1
County: Anderson (001)	**Truck % (1% MIN):** 1%
Structure # : CCCC-SS-SSS	**EV Daily Crossing:** 1 **(1 or 10)** One Direction
Bridge Description Roadway Over Stream	**Year Built:** 1995
	Railcar Descr: 3 Span Flatcar

Flatcar Properties Calculator

Flatcar Segment Description: Midspan Section

Total Depth of Flatcar Segment (in): 30.000 in

Plate Section(s) [Rectangular]	# of Sections	b [in]	h [in]	$A_{Individual}$ [in^2]	A_{Total} [in^2]	Y [in]	A_{Total}*Y [in^3]	$I_{Individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
28.75" x 5/16" Side Plate	2	0.313	28.750	8.984	17.969	15.250	274.023	618.85	1237.69	400.600
7/8" x 24" Bottom Plate	1	24.000	0.875	21.000	21.000	0.438	9.198	1.34	1.34	8012.855
3/8" 83" Top Plate	1	83.000	0.375	31.125	31.125	29.813	927.930	0.36	0.36	3014.507
				0.000	0.000		0.000	0.00	0.00	0.000
				0.000	0.000		0.000	0.00	0.00	0.000
Rolled Section(s) [Non-Rectangular]	**# of Sections**	-	-	$A_{Individual}$ [in^2]	A_{Total} [in^2]	Y [in]	A_{Total}*Y [in^3]	$I_{Individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
C15 x 33.9	2	-	-	10.000	20.000	22.500	450.000	315.00	630.00	127.848
HP14 x 73	2	-	-	21.400	42.800	23.200	992.960	729.00	1458.00	446.065
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
			Σ =		132.89 in^2	Σ =	2654.1 in^3	Σ =	3327 in^4	12002 in^4
									+	3327 in^4
									I_x =	**15329 in^4**

$W_{Segment}$ = ΣA*0.49/144 = **0.452 kip/ft**

y_{Bot} = ΣA*y/ΣA = 19.972 in

$S_{x\text{-}Bot}$ = **I_x/y_{Bot} = 767.551 in^3**

y_{Top} = Depth - y_{Bot} = 10.028 in

$S_{x\text{-}Top}$ = **I_x/y_{Top} = 1528.598 in^3**

Flatcar Properties Calculator

Flatcar Segment Description: End Section

Total Depth of Flatcar Segment (in): 15.000 in

Plate Section(s) [Rectangular]	# of Sections	b [in]	h [in]	$A_{Individual}$ [in^2]	A_{Total} [in^2]	Y [in]	A_{Total}*Y [in^3]	$I_{Individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
3/8" x 83" Top Plate	1	83.000	0.375	31.125	31.125	14.813	461.055	0.36	0.36	1124.053
28.75" x 5/16" Side Plate	2	0.313	12.125	3.789	7.578	8.563	64.891	46.42	92.84	0.438
7/8" x 24" Bottom Plate	1	24.000	1.000	24.000	24.000	2.000	48.000	2.00	2.00	1110.901
				0.000	0.000		0.000	0.00	0.00	0.000
				0.000	0.000		0.000	0.00	0.00	0.000
Rolled Section(s) [Non-Rectangular]	**# of Sections**	-	-	$A_{Individual}$ [in^2]	A_{Total} [in^2]	Y [in]	A_{Total}*Y [in^3]	$I_{Individual}$ [in^4]	I_{total} [in^4]	$A*(y_b-Y)^2$ [in^4]
C15 x 33.9	2	-	-	10.000	20.000	7.500	150.000	315.00	630.00	33.982
HP14 x 73	2	-	-	21.400	42.800	8.900	380.920	729.00	1458.00	0.399
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
		-	-		0.000		0.000		0.00	0.000
			Σ =		125.50 in^2	Σ =	1104.9 in^3	Σ =	2183 in^4	2270 in^4
									+	2183 in^4
									I_x =	**4453 in^4**

$W_{Segment}$ = ΣA*0.49/144 = **0.427 kip/ft**

y_{Bot} = ΣA*y/ΣA = 8.803 in

$S_{x\text{-}Bot}$ = **I_x/y_{Bot} = 505.820 in^3**

y_{Top} = Depth - y_{Bot} = 6.197 in

$S_{x\text{-}Top}$ = **I_x/y_{Top} = 718.628 in^3**

Steel Flatcar

Inputs

Number of Continuous Spans:	3		
Is First Span a Cantilever:	Yes		
Is Last Span a Cantilever:	No		
Span ID:	Cant. 1	Span 2	Span 3
Span Length (ft):	8.0	50.0	30.0
Number of Segments:	5	F_y (ksi):	36.0

CL-CL Flatcar Spacing (For LLDF):	12.17
Analyze 1 Truck per Flatcar?	Yes
Flatcar Width (for Dead Loads):	12.75

	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Segment Length (ft):	13.00	8.00	52.50	8.00	6.50
Start Moment of Inertia (in^4):	4453.0	4453.0	15329.0	15329.0	4453.0
Start $S_{x\text{-}Top}$ (in^3):	505.8	505.8	767.6	767.7	505.8
Start $S_{x\text{-}Bot}$ (in^3):	718.6	718.6	1528.6	1528.6	718.6
Start $W_{segment}$ (klf):	0.427	0.427	0.452	0.452	0.427
End Moment of Inertia (in^4):	4453.0	15329.0	15329.0	4453.0	4453.0
End $S_{x\text{-}Bot}$ (in^3):	505.8	767.6	767.6	505.8	505.8
End $S_{x\text{-}Top}$ (in^3):	718.6	1528.6	1528.6	718.6	718.6
End $W_{segment}$ (klf):	0.427	0.452	0.452	0.427	0.427
Misc. Dead Load per Segment (klf):	0.100	0.100	0.100	0.100	0.100

Import Values from Defined Deck Module: No Deck Import
Deck Type for Live Loads: Steel Plate Deck
Deck Type: Steel Plate Deck

Deck Thickness:	0.500	in *
Deck Weight:	0.020	ksf
Fill Weight:	0.000	ksf
Wearing Surface Weight:	0.000	ksf
Misc. Loads:	0.000	ksf

	LLDF S/	LLDF**	LLDF Ov.**	IM
Span 1:	-	2.00		1.30
Span 2:	-	2.00		1.29
Span 3:	-	2.00		1.30

*Deck thickness input as 0.500" for the 1/2" steel plate tack welded on top of the flatcar.
**LLDF defaults to 2.00 due to Analyze 1 Truck per Flatcar being set to "Yes". With deck width 12.17', only 2 wheel lines can be present on the deck.

Capacity

Tenth points within each Component are calculated for rating factors. The controlling location is shown below.

Controlling location:	20.5 ft		
Controlling Span:	2		
Controlling Segment:	3		
Controlling Component:	4		
C_u =	F_y*S = 36.0 ksi * 767.6 in3* (1 ft/12 in)	=	2302.8 ft-k

Dead Loads

Span 2 (Controlling):			
Deck + Misc. Deck Loads =	(0.020 ksf + 0.000 ksf) * 12.17 ft	=	0.243 klf
Flatcar =	(0.452 klf + 0.452 klf) / 2	=	0.452 klf
Misc Dead Load per Segment =		=	0.100 klf
Fill/Wearing Surface =	(0.000 ksf + 0.000 ksf) * 12.17 ft	=	0.000 klf
Total		=	0.795 klf

Dead Load and Live Load Moments

TBLRP-LFR estimates the dead and live load moments for continuous systems (flatcars, stringers, etc) by using influence lines. See Appendix A for more information.

The controlling location returns the following moments:

$Moment_{LL\text{ - }HS\text{-}20}$	=	239.7 ft-k
$Moment_{Distributed}$	=	479.4 ft-k
$Moment_{Dead\ Load}$	=	151.9 ft-k

Rating Factors

Positive Moment

HS-20 INV RF =	(2302.8 k-ft - 1.3 * 151.9 k-ft)/(2.17 * 479.4 k-ft * 1.29)	=	1.57	**HS 31.5**
HS-20 OPR RF =	(2302.8 k-ft - 1.3 * 151.9 k-ft)/(1.3 * 479.4 k-ft * 1.29)	=	2.63	**HS 52.6**

Note: Values above are rounded (not all decimals shown).

Appendix A

Table 1: Recommended Unit Weights for Materials

Recommended Unit Weights for Materials	
Material	**Unit Weight**
Concrete	0.150 kcf
Steel	0.490 kcf
Wood/Timber	0.050 kcf
Soil (Light)	0.100 kcf
Soil (Medium)	0.110 kcf
Soil (Heavy)	0.120 kcf
Gravel	0.125 kcf
Asphalt	0.145 kcf

Table 2: Structural Steel Allowable Yield Stress

Structural Steel Allowable Yield Stress	
Date Built	**Yield Stress**
Before 1905	26 ksi
1905-1936	30 ksi
1936-1963	33 ksi
After 1963	36 ksi

Table 3: Concrete Deck Allowable Compressive Stress

Concrete Deck Allowable Compressive Stress	
Date Built	**Compressive Stress**
Before 1959	2.5 ksi
1959-1982	3.0 ksi
1982-1993	3.6 ksi
After 1993	4.0 ksi

Typical Steel Member Shapes

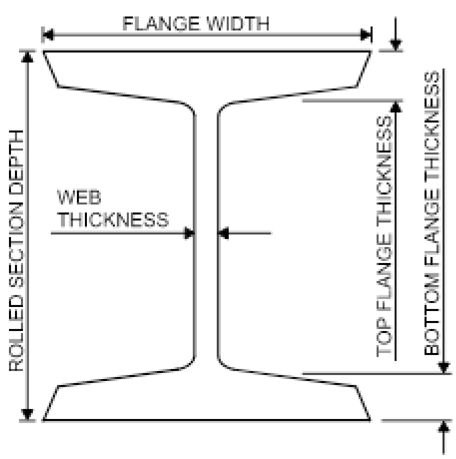


Figure 31: S-Shape

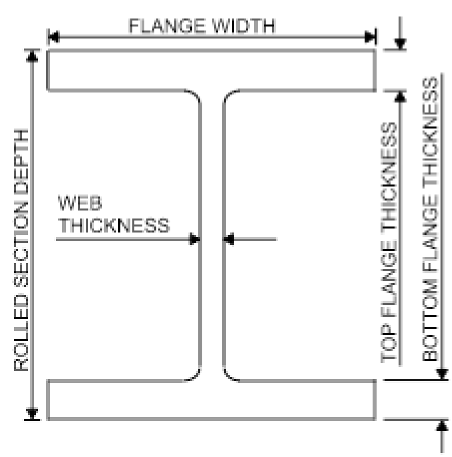


Figure 32: W-Shape

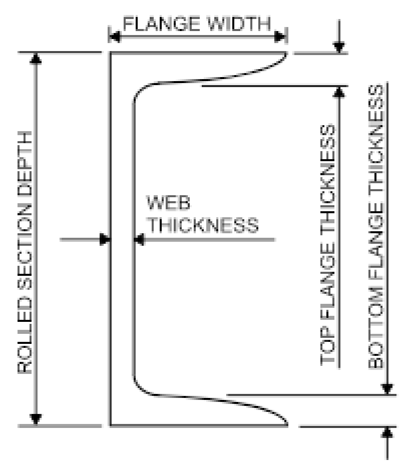


Figure 33: C-Channel

Appendix B

TBRLP-LFR Rating Vehicle Configurations

H/HS truck configurations From AASHTO 2002 LFD 17th Edition BDM:

3.7.3 Designation of Loadings

The policy of affixing the year to loadings to identify them was instituted with the publication of the 1944 Edition in the following manner:

H 15 Loading, 1944 Edition shall be designated..	H 15-44
H 20 Loading, 1944 Edition shall be designated..	H 20-44
H 15-S 12 Loading, 1944 Edition shall be designated..	HS 15-44
H 20-S 16 Loading, 1944 Edition shall be designated..	HS 20-44

The affix shall remain unchanged until such time as the loading specification is revised. The same policy for identification shall be applied, for future reference, to loadings previously adopted by AASHTO.

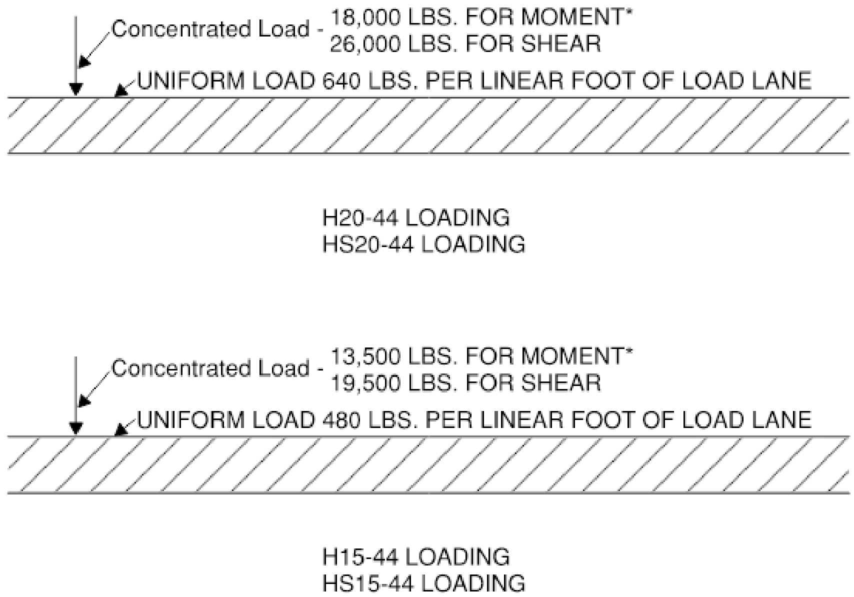


FIGURE 3.7.6B Lane Loading

*For the loading of continuous spans involving lane loading refer to Article 3.11.3 which provides for an additional concentrated load.

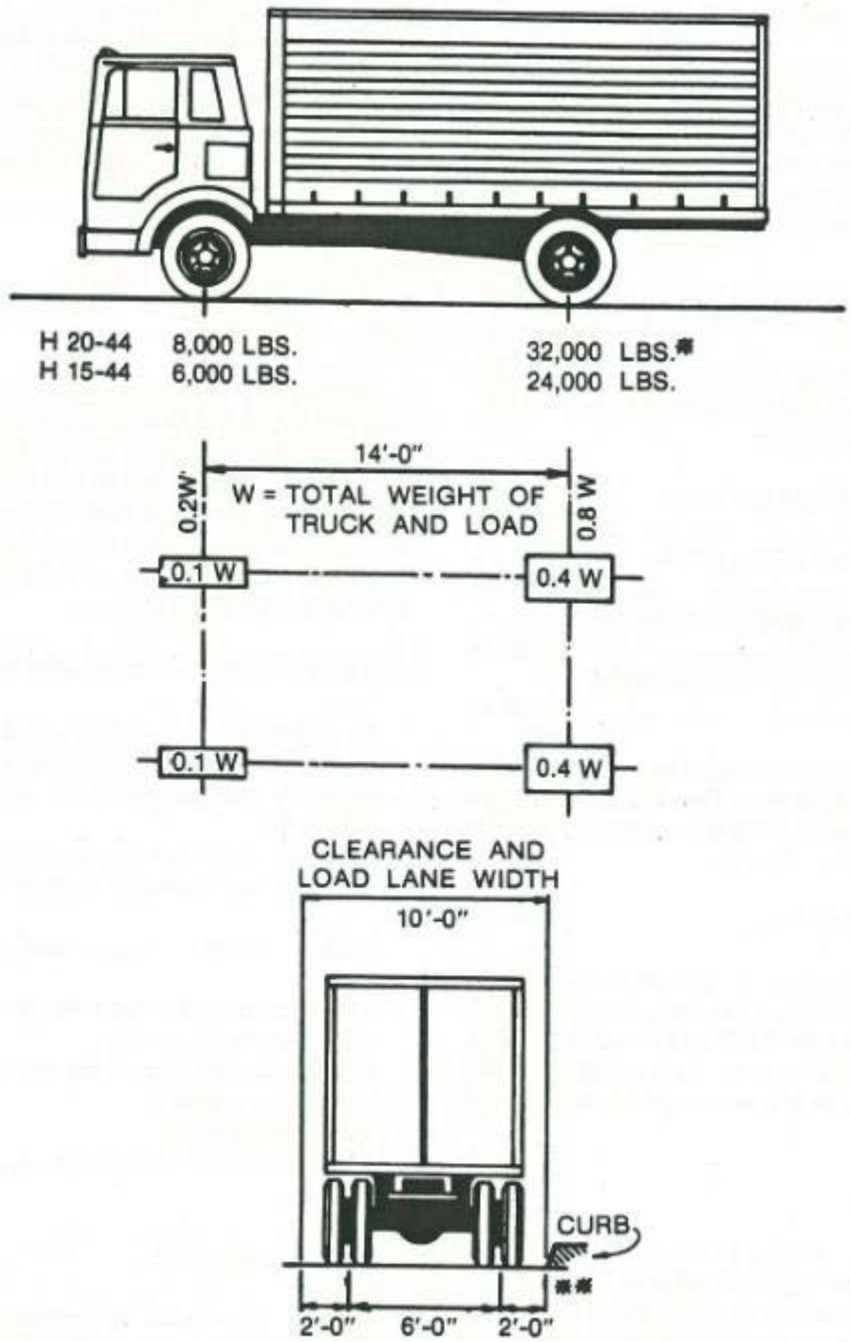


FIGURE 3.7.6A Standard H Trucks

*In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 Loading, one axle load of 24,000 pounds or two axle loads of 16,000 pounds each spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32,000-pound axle shown.

**For slab design, the center line of wheels shall be assumed to be 1 foot from face of curb. (See Article 3.24.2.)

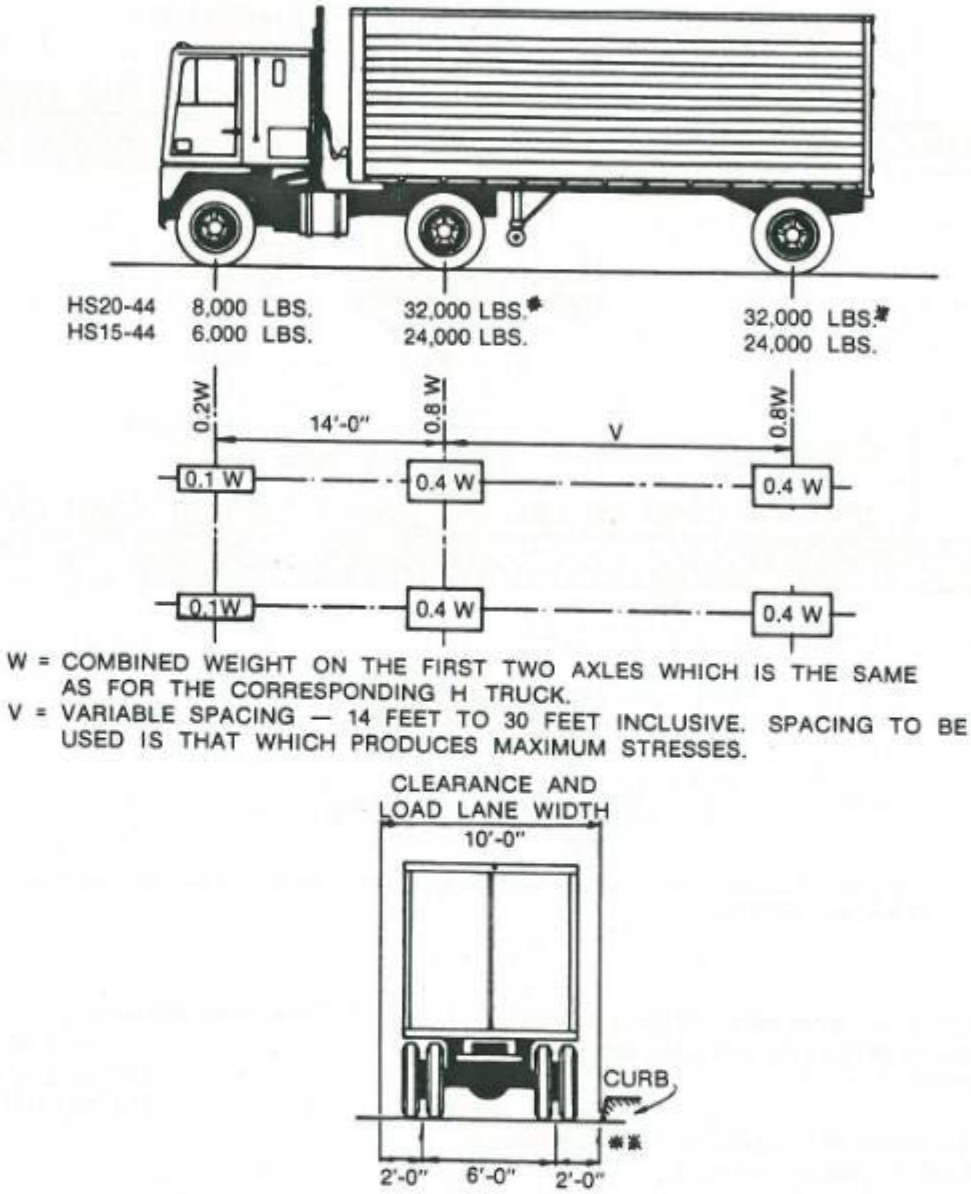


FIGURE 3.7.7A Standard HS Trucks

*In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 Loading, one axle load of 24,000 pounds or two axle loads of 16,000 pounds each, spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32,000-pound axle shown.

**For slab design, the center line of wheels shall be assumed to be 1 foot from face of curb. (See Article 3.24.2.)

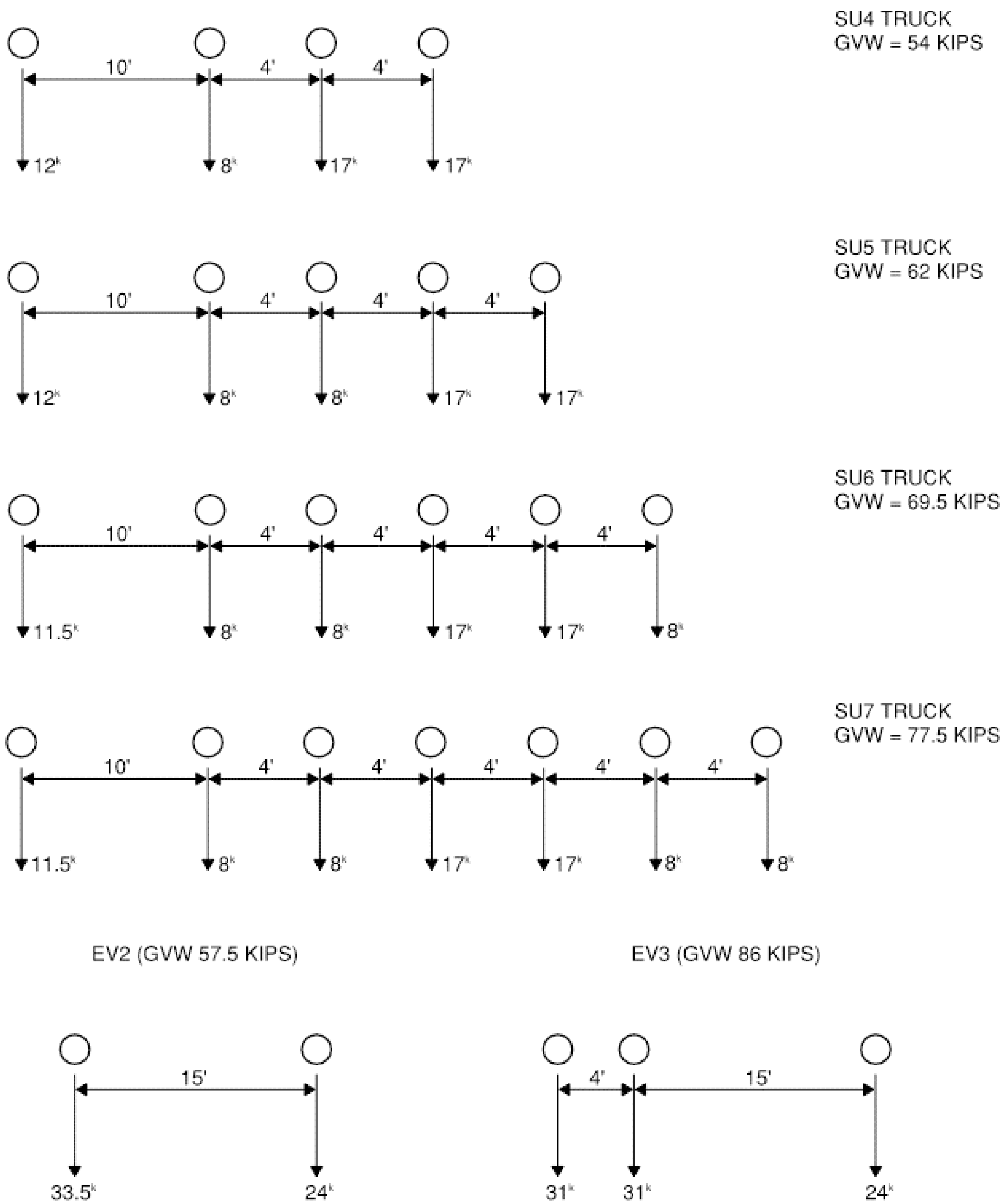


Figure 34: Truck Configuration Visual (SHVs and EVs)

Not drawn to scale

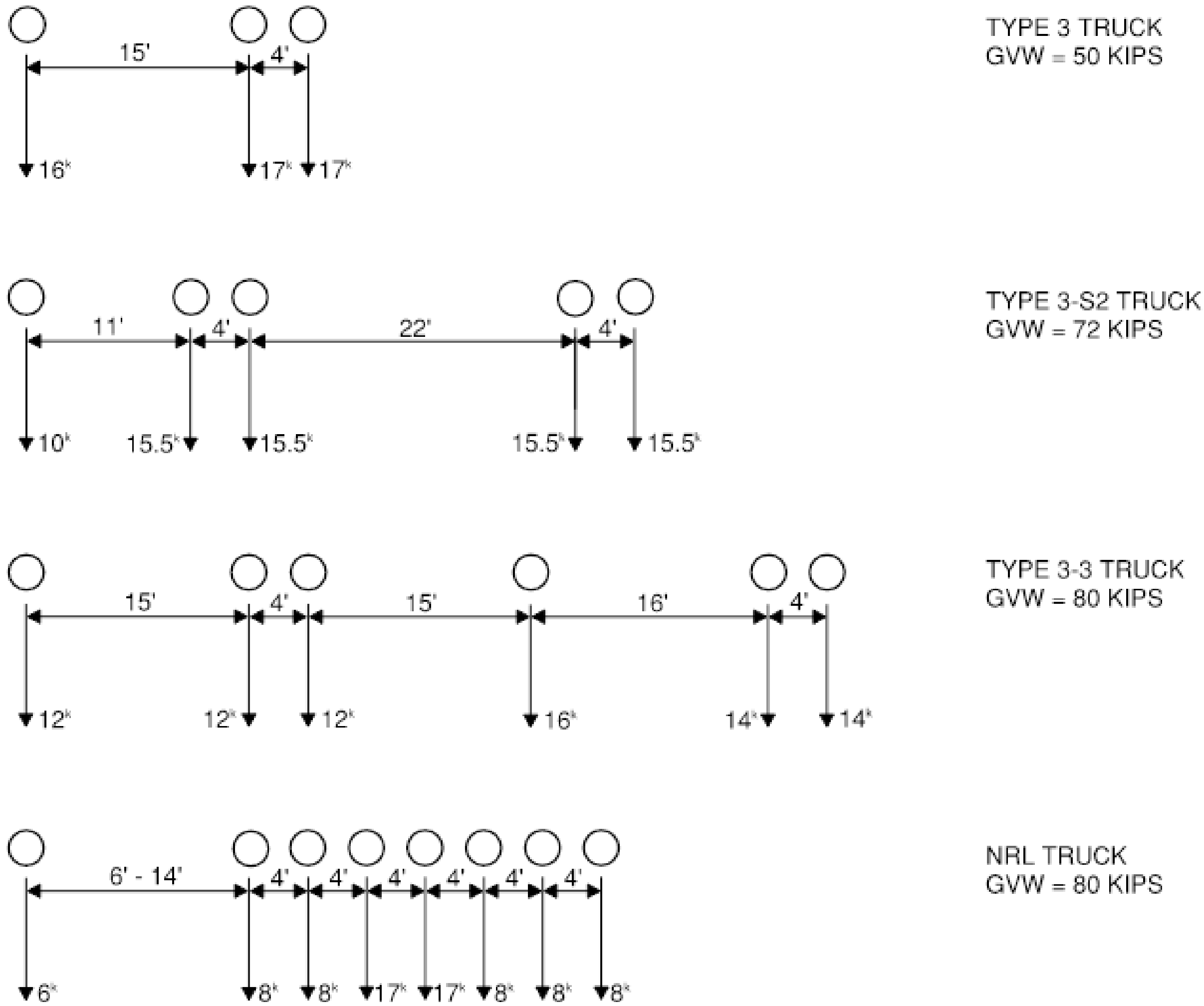


Figure 35: Truck Configuration Visual (AASHTO T Trucks and NRL Truck)

Not drawn to scale

Appendix C

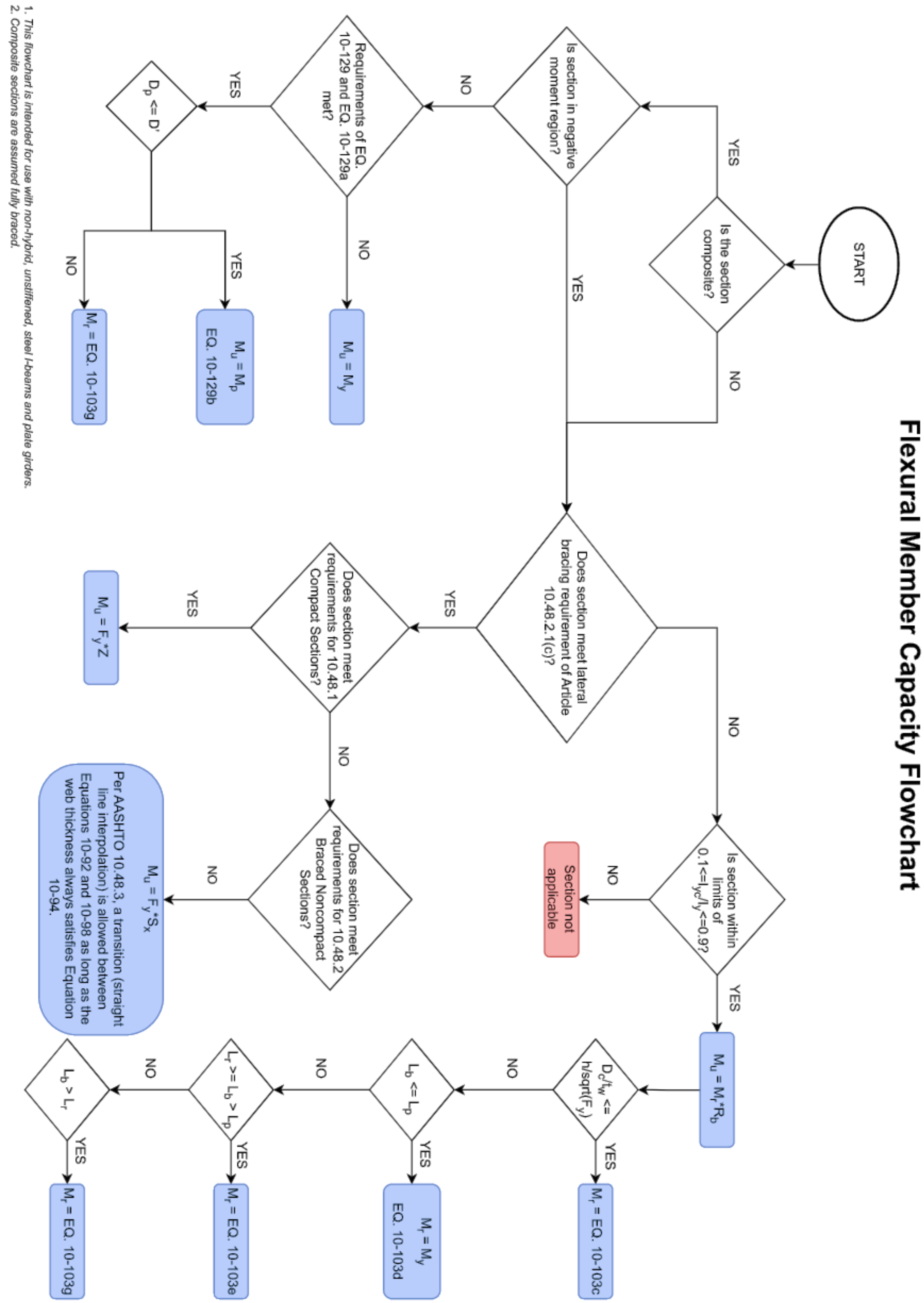


Figure 36: Flexural Member Capacity Flowchart

Appendix D

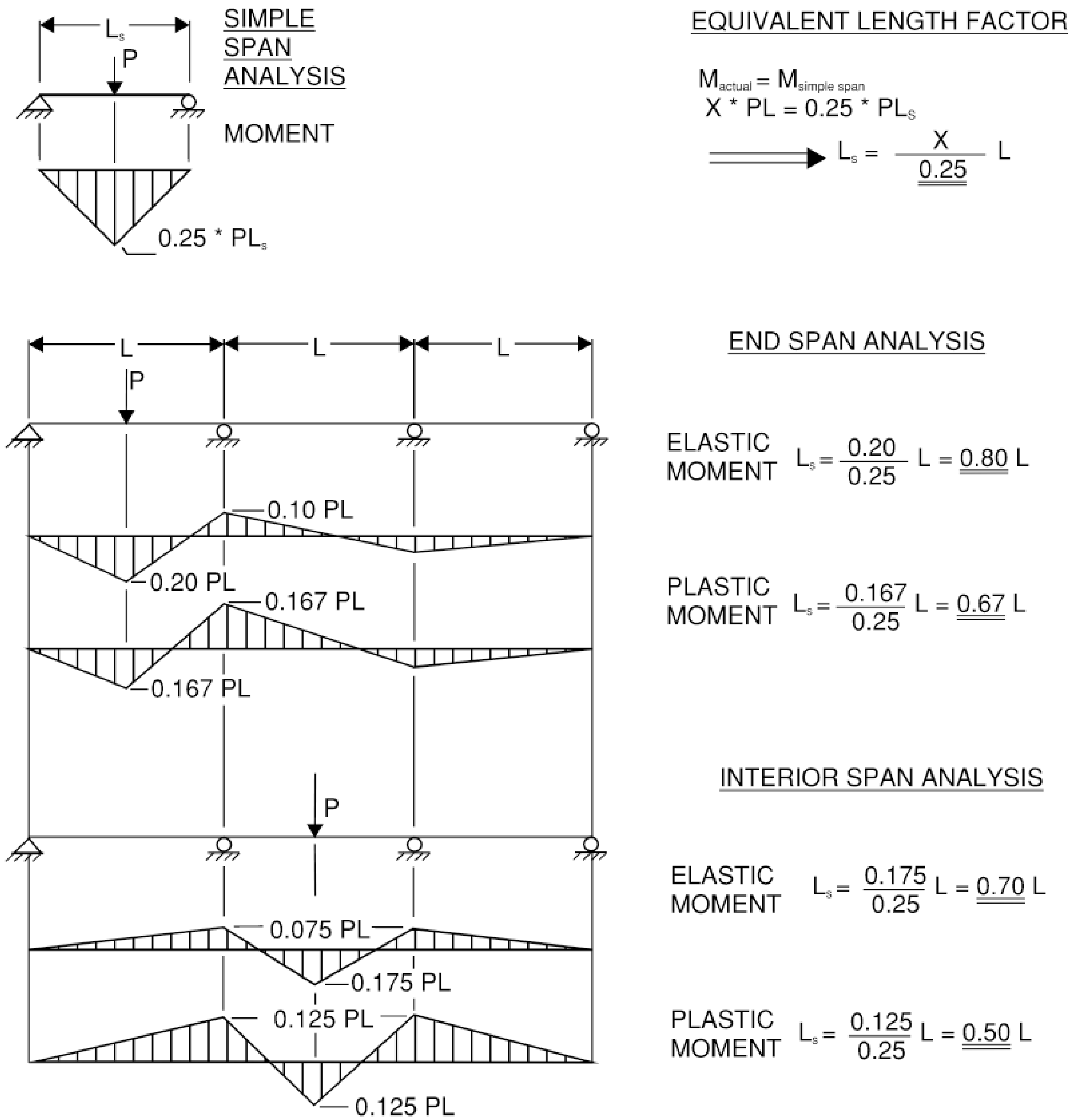


Figure 37: Derivation of Equivalent Simple Span Lengths

Appendix E

Development of Stiffness Matrix and Load Vector for Variable Section Member

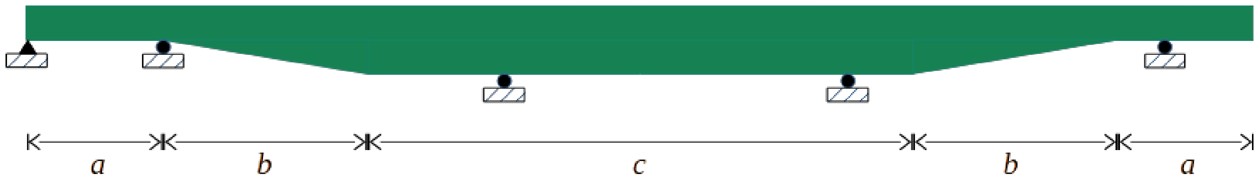


Figure 38: Variable Section Member Diagram

Tapered member stiffness matrix:

Left tapered segment:

$$A(x) = [\ \alpha(x)\ ]\ A_1$$

$$I(x) = [\ \alpha(x)\ ]^3\ I_1$$

$$\alpha_1 = 1, \alpha_2 = [\tfrac{I_2}{I_1}]^{\frac{1}{3}}$$

$$m = \frac{\alpha_2 - \alpha_1}{b} = \frac{\alpha(x) - \alpha_1}{x}$$

$$\alpha(x) = 1 + mx$$

$$I(x) = [\ \alpha_1 + mx\ ]^3\ I_1$$

$$I(x) = [1 + mx\ ]^3\ I_1 \qquad [\ 1\ ]$$

Right tapered segment:

$$I(x) = [\ 1 + m\ (L - x)\ ]^3\ I_1 \qquad [\ 2\ ]$$

Consider flexural effects only; axial and shear effects are neglected. The transverse displacements are considered positive when upwards, and rotations are considered positive when counterclockwise. Using virtual work:

$$\Delta_i\ /\ \Theta_i = \int_0^L \frac{1}{EI} M_i(x)\ m_i(x)\ \ dx \qquad \delta_{ij} / \ \theta_{ij} = \int_0^L \frac{1}{EI} m_i(x)\ m_j(x)\ \ dx$$

The transverse displacement and rotation at node "i" due to bending are given by:

$$v_i = \int_0^L \frac{1}{EI(x)} [-M_i + V_i\ x\ ]\ [x]\ \ dx$$

$$v_i = [\int_0^L \frac{x^2}{[\ 1\ +\ mx\ ]^3} dx\ ] \frac{1}{EI_1}\ V_i - [\int_0^L \frac{x}{[\ 1\ +\ mx\ ]^3} dx\ ] \frac{1}{EI_1}\ M_i \qquad [\ 3\ ]$$

$$\theta_i = \int_0^L \frac{1}{EI(x)} [-M_i + V_i\ x\ ]\ [-1]\ \ dx$$

$$\theta_i = -[\int_0^L \frac{x}{[\ 1\ +\ mx\ ]^3} dx\ ] \frac{1}{EI_1}\ V_i + [\int_0^L \frac{1}{[\ 1\ +\ mx\ ]^3} dx\ ] \frac{1}{EI_1}\ M_i \qquad [\ 4\ ]$$

The transverse displacement and rotation at node "j" due to bending are given by:

$$v_j = \int_0^L \frac{1}{EI(x)} [-M_i + V_i\, x\,]\, [L - x]\;\; dx$$

$$v_j = [-\int_0^L \frac{L\, -\, x}{[\,1\, +\, mx\,]^3} dx\,] \frac{1}{EI_1}\; M_i + [\,\int_0^L \frac{L\,x\, -\, x^2}{[\,1\, +\, mx\,]^3} dx\,] \frac{1}{EI_1}\; V_i$$

$$v_j = [\,L\; \int_0^L \frac{x}{[\,1\, +\, mx\,]^3} dx - \int_0^L \frac{x^2}{[\,1\, +\, mx\,]^3} dx\,] \frac{1}{EI_1}\; V_i - \\ [\,L \int_0^L \frac{1}{[\,1\, +\, mx\,]^3} dx - \int_0^L \frac{x}{[\,1\, +\, mx\,]^3} dx\,] \frac{1}{EI_1}\; M_i \qquad [\,5\,]$$

$$\theta_j = \int_0^L \frac{1}{EI(x)} [-M_i + V_i\, x\,]\, [1]\;\; dx$$

$$\theta_j = [\,\int_0^L \frac{x}{[\,1\, +\, mx\,]^3} dx\,] \frac{1}{EI_1}\; V_i - [\,\int_0^L \frac{1}{[\,1\, +\, mx\,]^3} dx\,] \frac{1}{EI_1}\; M_i \qquad [\,6\,]$$

Then, the transverse displacement and rotation at node "i" due to bending are given by:

$v_i = a_{11}\, V_i + a_{12}\, M_i$ $\qquad$ $v_j = a_{31}\, V_i + a_{32}\, M_i$

$\theta_i = a_{21}\, V_i + a_{22}\, M_i$ $\qquad$ $\theta_j = a_{41}\, V_i + a_{42}\, M_i$

DOF $v_i = 1$:
The stiffness coefficients due to a unit transverse displacement at node "i" are found by setting $v_i = 1$ with $v_j = \theta_i = \theta_j = 0$ and solving for V_i and M_i:

$$a_{11}\, V_i + a_{12}\, M_i = 1$$

$$a_{21}\, V_i + a_{22}\, M_i = 0$$

The stiffness coefficients V_j and M_j at node "j" are found by equilibrium.

$k_{11},\ \ k_{12},\ \ k_{13},\ \ k_{14}$

DOF $\theta_i = 1$:
The stiffness coefficients due to a unit rotation at node "i" are found by setting $\theta_i = 1$ with $v_i = v_j = \theta_j = 0$ and and solving for V_i and M_i:

$$a_{11}\, V_i + a_{12}\, M_i = 0$$

$$a_{21}\, V_i + a_{22}\, M_i = 1$$

The stiffness coefficients V_j and M_j at node "j" are found by equilibrium.

$k_{21},\ \ k_{22},\ \ k_{23},\ \ k_{24}$

DOF $v_j = 1$:
The stiffness coefficients due to a unit transverse displacement at node "j" are found by setting $v_j = 1$ and $v_i = \theta_i = \theta_j = 0$ and solving for V_i and M_i:

$$a_{11}\, V_i + a_{12}\, M_i = 1$$

$$a_{21}\, V_i + a_{22}\, M_i = 0$$

The stiffness coefficients V_j and M_j at node "j" are found by equilibrium.

$k_{31},\ \ k_{32},\ \ k_{33},\ \ k_{34}$

DOF $\theta_j = 1$:
The stiffness coefficients due to a unit rotation at node "i" are found by setting $\theta_j = 1$ with $v_i = v_j = \theta_i = 0$ and solving for V_i and M_i:

$$a_{11}\, V_i + a_{12}\, M_i = 1$$

$$a_{21}\, V_i + a_{22}\, M_i = 0$$

The stiffness coefficients V_j and M_j at node "j" are found by equilibrium.

$k_{41},\ \ k_{42},\ \ k_{43},\ \ k_{44}$

Tapered member load vector:

Self-weight load w:

The self-weight is not uniform due to its variable cross section:

$$w(x) = \gamma_{steel}\, \alpha(x)\, A_1$$
$$\alpha(x) = 1 + mx$$
$$w(x) = \gamma_{steel}\, A_1(1 + mx)$$

$$w(x) = w\,(1 + mx)$$
$$w = \gamma_{steel}\, A_1$$

The bending moment at x:

$$M(x) = (-w)(x)\,[\frac{1}{2}x] + \frac{1}{2}(-mwx)(x)\,[\frac{1}{3}x]$$
$$M(x) = -\frac{1}{2}w\,x^2 - \frac{1}{6}mw\,x^3$$

The transverse displacement and rotation at node "i" are given by:

$$v_i = \int_0^L \frac{1}{EI(x)}[-M_i + V_i\,x + M(x)]\,[x]\ dx$$
$$v_i = -[\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ M_i + [\int_0^L \frac{x^2}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ V_i + [\int_0^L \frac{[-\frac{1}{2}w\,x^2\ -\ \frac{1}{6}mw\,x^3]\,(x)}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}$$

$$v_i = -[\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ M_i + [\int_0^L \frac{x^2}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ V_i - [\frac{1}{2}w\int_0^L \frac{x^3}{[\,1\,+\,mx\,]^3}dx + \frac{1}{6}mw\int_0^L \frac{x^4}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1} \qquad [\,7\,]$$

$$\theta_i = \int_0^L \frac{1}{EI(x)}[-M_i + V_i\,x + M(x)\,]\,[-1]\ dx$$
$$\theta_i = [\int_0^L \frac{1}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ M_i - [\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ V_i - [\int_0^L \frac{[-\frac{1}{2}w\,x^2\ -\ \frac{1}{6}mw\,x^3]}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}$$

$$\theta_i = [\int_0^L \frac{1}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ M_i - [\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\ V_i + [\frac{1}{2}w\int_0^L \frac{x^2}{[\,1\,+\,mx\,]^3}dx + \frac{1}{6}mw\int_0^L \frac{x^3}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1} \qquad [\,8\,]$$

The FEM, fixed end moments, at node "i" are found by setting $v_i = 0$ and $\theta_i = 0$ and solving for V_i and M_i:

$$a_{11}\,V_i + a_{12}\,M_i + a_{13} = 0$$
$$a_{21}\,V_i + a_{22}\,M_i + a_{23} = 0$$

The FEM at node "j" is found by equilibrium.

Distributed load w:

Distributed linear varying load, $w_i$and w_j at ends "i" and "j", respectively.

$$w(x) = w_i + n\,x$$
$$n = \frac{1}{L}(w_j - w_i)$$
$$w(x) = w_i + \frac{1}{L}(w_j - w_i)\,x$$

The bending moment at x:

$$M(x) = (w_i)(x)\,[\frac{1}{2}x] + \frac{1}{2}(nx)(x)\,[\frac{1}{3}x]$$
$$M(x) = \frac{1}{2}w_i\,x^2 + \frac{1}{6}n\,x^3$$

The transverse displacement and rotation at node "i" are given by:

$$v_i = \int_0^L \frac{1}{EI(x)}[-M_i + V_i\,x + M(x)]\,[x]\;dx$$
$$v_i = -[\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;M_i + [\int_0^L \frac{x^2}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;V_i$$
$$+\,[\int_0^L \frac{[\frac{1}{2}w_i\,x^2\;+\;\frac{1}{6}n\,x^3]\;(x)}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}$$

$$v_i = -[\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;M_i + [\int_0^L \frac{x^2}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;V_i + [\frac{1}{2}w_i\int_0^L \frac{x^3}{[\,1\,+\,mx\,]^3}dx + \frac{1}{6}n\int_0^L \frac{x^4}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1} \qquad [\,9\,]$$

$$\theta_i = \int_0^L \frac{1}{EI(x)}[-M_i + V_i\,x + M(x)\,]\,[-1]\;dx$$
$$\theta_i = [\int_0^L \frac{1}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;M_i - [\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;V_i$$
$$-\,[\int_0^L \frac{[\frac{1}{2}w_i\,x^2\;+\;\frac{1}{6}n\,x^3]}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}$$
$$\theta_i = [\int_0^L \frac{1}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;M_i - [\int_0^L \frac{x}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1}\;V_i - [\frac{1}{2}w_i\int_0^L \frac{x^2}{[\,1\,+\,mx\,]^3}dx + \frac{1}{6}n\int_0^L \frac{x^3}{[\,1\,+\,mx\,]^3}dx\,]\frac{1}{EI_1} \qquad [\,10\,]$$

The FEM, fixed end moments, at node "i" are found by setting $v_i = 0$ and $\theta_i = 0$ and solving for V_i and M_i:

$$a_{11}\,V_i + a_{12}\,M_i + a_{13} = 0$$
$$a_{21}\,V_i + a_{22}\,M_i + a_{23} = 0$$

The FEM at node "j" is found by equilibrium.

Concentrated load P at $x = x_a$

The bending moment at x:

$$M(x) = P < x - x_a >$$

The transverse displacement and rotation at node "i" are given by:

$$v_i = \int_0^L \frac{1}{EI(x)} [-M_i + V_i\, x + M(x)]\, [x]\ dx$$

$$v_i = -[\int_0^L \frac{x}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ M_i + [\int_0^L \frac{x^2}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ V_i$$
$$+ [\int_0^L \frac{P\ < x\ -\ x_a >\ (x)}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}$$

$$v_i = -[\int_0^L \frac{x}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ M_i + [\int_0^L \frac{x^2}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ V_i + [\,P \int_{x_a}^L \frac{x^2}{[\,1\ +\ mx\,]^3} dx - \ x_a \int_{x_a}^L \frac{x}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1} \qquad [\,11\,]$$

$$\theta_i = \int_0^L \frac{1}{EI(x)} [-M_i + V_i\, x + M(x)\,]\, [-1]\ dx$$

$$\theta_i = [\int_0^L \frac{1}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ M_i - [\int_0^L \frac{x}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ V_i - [\int_0^L \frac{P\ < x\ -\ x_a >}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}$$

$$\theta_i = [\int_0^L \frac{1}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ M_i - [\int_0^L \frac{x}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1}\ V_i - [\,P \int_{x_a}^L \frac{x}{[\,1\ +\ mx\,]^3} dx - x_a \int_{x_a}^L \frac{1}{[\,1\ +\ mx\,]^3} dx\,] \frac{1}{EI_1} \qquad [\,12\,]$$

The FEM, fixed end moments, are found by setting $v_i = 0$ with $\theta_i = 0$ and solving for M_i and V_i:

$$a_{11}\, V_i + a_{12}\, M_i + a_{13} = 0$$
$$a_{21}\, V_i + a_{22}\, M_i + a_{23} = 0$$

The FEM at node "j" is found by equilibrium.

Appendix F

Influence lines for Bending Moment using Muller-Breslau's Principle

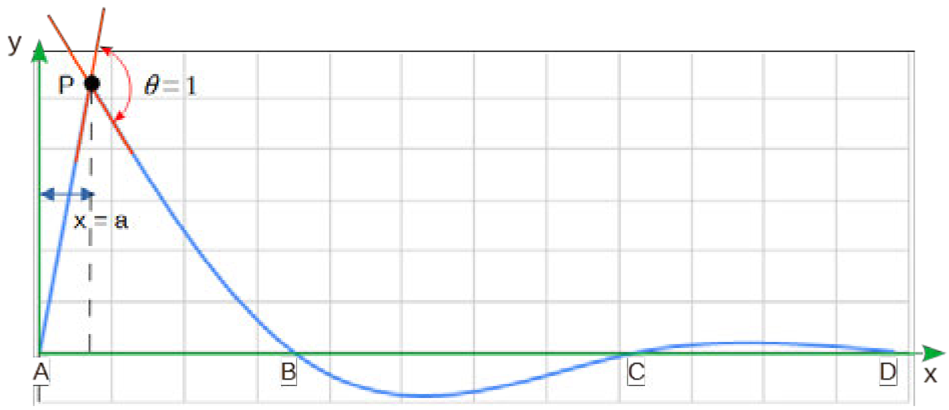


Figure 39: Influence lines for Bending Moment using Muller-Breslau's Principle

Consider the three span continuous system with spans AB, BC, and CD, the bending moment influence line for a section at $x = a$, can be found using the Muller-Breslau principle. The principle states that if <u>the continuity at the section $P\ (x = a)$ is removed and a relative unit rotation is applied, by introducing an artificial hinge, the resulting deflected shape of the system represents the bending moment influence line for this section.</u>

Assuming the section geometry of the beam (moment of inertia) and the material properties (elastic modulus) are known, the equation for the deflected shape as a function of the displacement, rotation, shear force and bending moment v_A, θ_A, V_A and M_A at the end A is given by:

$$y''(x) = \frac{1}{EI(x)} M(x) = \frac{1}{EI(x)} [-M_A + V_A\, x]$$

$$y'(x) = -[\int_0^x \frac{1}{EI(x)} dx\,]\, M_A + [\int_0^x \frac{x}{EI(x)} dx\,]\, V_A + C_1 \qquad [\,1\,]$$

$$y(x) = -[\int_0^x [\int_0^x \frac{1}{EI(x)} dx\,]\, dx\,]\, M_A + [\int_0^x [\int_0^x \frac{x}{EI(x)} dx\,]\ dx\,]\, V_A + C_1 x + C_2$$

Considering a rotation θ_A, where counterclockwise is positive, at end A:

At $x = 0$, $\quad y'(0) = \theta_A$

$$\theta_A = -[0]\, M_A + [0]\, V_A + C_1$$

$$C_1 = \theta_A \qquad [\,2\,]$$

Considering a deflection v_A, where upward is positive, at end A:

At $x = 0$, $\quad y(0) = v_A$

$$v_A = -[0]\, M_A + [0]\, V_A + C_1(0) + C_2$$

$$C_2 = v_A \qquad [\,3\,]$$

Thus, from [2] and [1] the equation for the slope of the beam is given by:

$$y'(x) = -M_A \, [\int_0^x \frac{1}{EI(x)} dx \,] + V_A \, [\int_0^x \frac{x}{EI(x)} dx \,] + \theta_A \qquad [\ 4\ ]$$

From [3] and [1] the equation for the deflected shape of the beam is given by:

$$y(x) = -M_A \, \{ \int_0^x [\int_0^x \frac{1}{EI(x)} dx \,] \, [\ dx \, \} + V_A \, \{ \int_0^x [\int_0^x \frac{x}{EI(x)} dx \,] \ dx \, \} + \theta_A \, x + v_A \qquad [\ 5\ ]$$

The values for V_A and M_A due to the singularity at $x = a$, representing the unit rotation a this section, can be found by using the boundary conditions at end B. From [4] and [5], the slope and the deflected shape for the span AB due to the singularity are:

$$y'(x) = -M_A \, \{ \int_0^x \frac{1}{EI(x)} dx \, \} + V_A \, \{ \int_0^x \frac{x}{EI(x)} dx \, \} + \theta_A + < x - a >^0$$

$$y'(x) = -A(x) \frac{1}{EI_1} \, M_A + B(x) \frac{1}{EI_1} V_A + \theta_A + < x - a >^0$$

From Integrals Table:

$$A(x) = \int_0^x \frac{1}{[\ 1 \ + \ mx\ ]^3} \ dx = -\{\frac{1}{2m}\}[\frac{1}{(1 \ + \ mx)^2} - 1] \qquad [\ 6\ ]$$

$$B(x) = \int_0^x \frac{x}{[\ 1 \ + \ mx\ ]^3} \ dx = -\{\frac{1}{2m}\}[\frac{x}{(1 \ + \ mx)^2}] - \{\frac{1}{2m^2}\}[\frac{1}{(1 \ + \ mx)} - 1]$$

$$y(x) = -\{ \int_0^x A(x) \ dx \, \} \frac{1}{EI_1} M_A + \{ \int_0^x B(x) \ dx \, \} \frac{1}{EI_1} V_A + \theta_A \, x + v_A + < x - a >^1$$

$$y(x) = -C(x) \frac{1}{EI_1} \, M_A + D(x) \frac{1}{EI_1} V_A + \theta_A \, x + v_A + < x - a >^1$$

From Integrals Table:

$$C(x) = \int_0^x A(x) \ dx = -\{\frac{1}{2m}\} \int_0^x [\frac{1}{[\ 1 \ + \ mx\ ]^2} - 1] \, dx = \{\frac{1}{2m^2}\}[\frac{1}{(1 \ + \ mx)} - 1] + \{\frac{1}{2m}\} \, [x] \qquad [\ 7\ ]$$

$$D(x) = \int_0^x B(x) \ dx = \int_0^x [-\{\frac{1}{2m}\}[\frac{x}{(1 \ + \ mx)^2}] - \{\frac{1}{2m^2}\}[\frac{1}{(1 \ + \ mx)} - 1]] \, [\, dx$$

$$= \{\frac{1}{2m^2}\}[\frac{x}{(1 \ + \ mx)}] - \frac{1}{m^3} [\, ln|1 + mx| \,] + \{\frac{1}{2m^2}\} \, [x]$$

Where the singularity function is defined as:

$$< x - a > = \begin{vmatrix} 0 & x < a \\ x - a & x \geq a \end{vmatrix} \qquad [\ 8\ ]$$

Note that the constants C_1 and C_2 in [2] and [3] remain unchanged since the singularity term $< x - a >$ vanishes for $x < a$ (at end A, $x = 0$).

Considering a rotation θ_B, where counterclockwise is positive, at end B:

At $x = L$: $\quad y'(L) = \theta_B$

$$\theta_B = \theta_A - \frac{A}{EI_1} M_A + \frac{B}{EI_1} V_A + 1 \qquad [\,9\,]$$

Likewise, considering a deflection v_B, where upwards is positive, at end B:

At $x = L$: $\quad y(L) = v_B$

$$v_B = v_A + \theta_A\,(L) - \frac{C}{EI_1} M_A + \frac{D}{EI_1} V_A + (L - a) \qquad [\,10\,]$$

Rearranging [9] and [10]:

$$B\,V_A - A\,M_A = [\,\theta_B - \theta_A - 1\,]\,EI_1 \qquad [\,11\,]$$

$$D\,V_A - C\,M_A = [v_B - v_A - \theta_A L - (L - a)\,]\,EI_1 \qquad [\,12\,]$$

Solving for V_A and M_A from [11] and [12] using Cramer's Rule:

$$V_A = \frac{\begin{vmatrix} [\,\theta_B - \theta_A - 1\,]\,EI_1 & -A \\ [v_B - v_A - \theta_A L - (L - a)\,]\,EI_1 & -C \end{vmatrix}}{\begin{vmatrix} B & -A \\ D & -C \end{vmatrix}}$$

$$V_A = \frac{1}{(-\,BC + AD)}\{-C\,[\,\theta_B - \theta_A - 1\,]\,EI_1 + A\,[v_B - v_A - \theta_A L - (L - a)\,]\,EI_1\}$$

$$V_A = \frac{1}{(-\,BC + AD)}\{-A\,[v_A - v_B\,] + [(C - A\,L)\,\theta_A - C\,\theta_B\,] + [C - A\,(L - a)\,]\,\}\,EI_1 \qquad [\,13\,]$$

$$M_A = \frac{\begin{vmatrix} B & [\,\theta_B - \theta_A - 1\,]\,EI_1 \\ D & [v_B - v_A - \theta_A L - (L - a)\,]\,EI_1 \end{vmatrix}}{\begin{vmatrix} B & -A \\ D & -C \end{vmatrix}}$$

$$M_A = \frac{1}{(-\,BC + AD)}\{\,B\,[v_B - v_A - \theta_A L - (L - a)\,]\,EI_1 - D\,[\,\theta_B - \theta_A - 1\,]\,EI_1\}$$

$$M_A = \frac{1}{(-\,BC + AD)}\{-B\,[v_A - v_B\,] + [(D - BL)\,\theta_A - D\,\theta_B\,] + [D - B\,(L - a)\,]\,\}\,EI_1 \qquad [\,14\,]$$

The third term in equations [13] and [14] represents the equivalent fixed end forces at end A due to the singularity at $x = a$, hence:

$$FEF\ V_A = [\frac{C - A\,(L - a)}{-BC + AD}]\ EI_1$$

$$FEF\ M_A = [\frac{D - B\,(L - a)}{-BC + AD}]\ EI_1 \qquad [\ 15\ ]$$

By equilibrium, the equivalent fixed end forces at end B due to the singularity at $x = a$ are:

$\sum\ F_y = 0$:
$FEF\ V_A + FEF\ V_B = 0$
$FEF\ V_B = -FEF\ V_A$

$\sum\ M_z = 0$:
$FEF\ V_A\ (L) - FEF\ M_A - FEF\ M_B = 0$
$FEF\ M_B = FEF\ V_A\ (L) - FEF\ M_A$

$$FEF\ V_B = -\ [\frac{C - A\,(L - a)}{-BC + AD}]\ EI_1$$

$$FEF\ M_B = [\frac{\{\ C - A\,(L - a)\ \}\ L - \{\ D - B\,(L - a)\ \}}{-BC + AD}]\ EI_1 \qquad [\ 16\ ]$$

$$FEF\ M_B = [\frac{(C\ L - D) + (B - A\ L)(L - a)}{-BC + AD}]\ EI_1$$

Finally, the influence line will be given by equations [5] and [7] with v_A and θ_A found from beam analysis, and V_A and M_A given by equations [13] and [14]:

$$y(x) = -\{\ \int_0^x A(x)\ dx\ \}\frac{1}{EI_1} M_A + \{\ \int_0^x B(x)\ dx\ \}\frac{1}{EI_1} V_A + \theta_A\,x + v_A + < x - a >^1$$

$$y(x) = -C(x)\frac{1}{EI_1}\ M_A + D(x)\frac{1}{EI_1}\ V_A + \theta_A\,x + v_A + < x - a >^1 \qquad [\ 17\ ]$$

Or equivalently:

$$y(x) = \begin{array}{ll} v_A + \theta_A\,x - C(x)\frac{1}{EI_1}\ M_A + D(x)\frac{1}{EI_1}\ V_A & x \le a \\ v_A + \theta_A\,x - C(x)\frac{1}{EI_1}\ M_A + D(x)\frac{1}{EI_1}\ V_A + x - a & x > a \end{array} \qquad [\ 18\ ]$$

where:

$$C(x) = \int_0^x A(x)\ dx = \frac{1}{2}[\frac{1}{m^2}][\frac{1}{(1 + mx)} - 1] + \frac{1}{2}[\frac{1}{m}]\ x$$

$$D(x) = \int_0^x B(x)\ dx = \frac{1}{2}[\frac{1}{m^2}][\frac{1}{(1 + mx)} + 1]\ x - \frac{1}{m^3}\ ln|1 + mx|$$

Tapered cross section:

$$y(x) = \begin{vmatrix} v_A + \theta_A\, x - C(x)\frac{1}{EI_1}\, M_A + D(x)\frac{1}{EI_1}\, V_A & x \le a \\ v_A + \theta_A\, x - C(x)\frac{1}{EI_1}\, M_A + D(x)\frac{1}{EI_1}\, V_A + x - a & x > a \end{vmatrix} \qquad [\ 19\ ]$$

where:

$$C(x) = \int_0^x \quad A(x)\, dx = \frac{1}{2}\,[\frac{1}{m^2}][\frac{1}{(1+mx)} - 1] + \frac{1}{2}\,[\frac{1}{m}]\, x$$

$$D(x) = \int_0^x \quad B(x)\, dx = \frac{1}{2}\,[\frac{1}{m^2}][\frac{1}{(1+mx)} + 1]\, x - \frac{1}{m^3}\ ln|1 + mx|$$

Constant cross section:

$$y(x) = \begin{vmatrix} v_A + \theta_A\, x - \frac{1}{2EI} M_A\, x^2 + \frac{1}{6EI} V_A\, x^3 & x \le a \\ v_A + \theta_A\, x - \frac{1}{2EI} M_A\, x^2 + \frac{1}{6EI} V_A\, x^3 + x - a & x > a \end{vmatrix} \qquad [\ 19a\ ]$$

$$y(x) = \begin{vmatrix} v_A + \theta_A\, x - [\,\frac{1}{2}x^2\,]\frac{1}{EI} M_A + [\,\frac{1}{6}x^3\,]\frac{1}{EI} V_A & x \le a \\ v_A + \theta_A\, x - [\,\frac{1}{2}x^2\,]\frac{1}{EI} M_A + [\,\frac{1}{6}x^3\,]\frac{1}{EI} V_A + x - a & x > a \end{vmatrix} \qquad [\ 19b\ ]$$

$$y(x) = \begin{vmatrix} v_A + \theta_A\, x - C(x)\frac{1}{EI}\, M_A + D(x)\frac{1}{EI}\, V_A & x \le a \\ v_A + \theta_A\, x - C(x)\frac{1}{EI}\, M_A + D(x)\frac{1}{EI}\, V_A + x - a & x > a \end{vmatrix} \qquad [\ 19c\ ]$$

where:

$$C(x) = \frac{1}{2}x^2$$

$$D(x) = \frac{1}{6}x^3$$

Coefficients $A(x), B(x), C(x)$, and $D(x)$:

$$A(x) = \int_0^x \frac{1}{[\,1\ +\ mx\,]^3}\,dx\ = \{-\frac{1}{2m}\}[\frac{1}{(1\ +\ mx)^2}]|_0^x$$

$$\boxed{\begin{aligned} A(x) &= \int_0^x \frac{1}{[\,1\ +\ mx\,]^3}\,dx \\ &= \{-\frac{1}{2m}\}[\frac{1}{(1\ +\ mx)^2} - 1] \\ A(x) &= \int_0^x dx\ = x\,|_0^x = x \end{aligned}}$$

$$B(x) = \int_0^x \frac{x}{[\,1\ +\ mx\,]^3}\,d\,x = -\{\frac{1}{2m}\}[\frac{x}{(1\ +\ mx)^2}]|_0^x - \{\frac{1}{2m^2}\}[\frac{1}{(1\ +\ mx)}]|_0^x$$

$$\boxed{\begin{aligned} B(x) &= \int_0^x \frac{x}{(1\ +\ mx)^3}\,dx = -\{\frac{1}{2m}\}[\frac{x}{(1\ +\ mx)^2}] - \{\frac{1}{2m^2}\}[\frac{1}{(1\ +\ mx)} - 1] \\ B(x) &= \int_0^x x\ dx = \frac{1}{2}x^2|_0^x = \frac{1}{2}x^2 \end{aligned}}$$

$$C(x) = \int_0^x A(x)\ dx = \int_0^x \{-\frac{1}{2m}\}[\frac{1}{(1\ +\ mx)^2} - 1]\ dx = \{-\frac{1}{2m}\}[\frac{1}{m}\frac{1}{(-1)}\frac{1}{(1\ +\ mx)} - x]|_0^x$$

$$\boxed{\begin{aligned} C(x) &= \int_0^x A(x)\ dx = \{\frac{1}{2m^2}\}[\frac{1}{(1\ +\ mx)} - 1] + \{\frac{1}{2m}\}\ [x] \\ C(x) &= \int_0^x [\ \int_0^x dx\ ]\ dx = \int_0^x x]\,[\ dx = \frac{1}{2}x^2|_0^x = \frac{1}{2}x^2 \end{aligned}}$$

$$D(x) = \int_0^x B(x)\ dx = \int_0^x \{-\{\frac{1}{2m}\}[\frac{x}{(1\ +\ mx)^2}] - \{\frac{1}{2m^2}\}[\frac{1}{(1\ +\ mx)} - 1]\ \}\ dx$$

$$D(x) = \int_0^x B(x)\ dx = -\{\frac{1}{2m}\}[-\frac{1}{m}[\frac{x}{(1\ +\ mx)}]|_0^x + \frac{1}{m}[\frac{1}{m}ln|1+mx|\ |_0^x\,]] - \{\frac{1}{2m^2}\}[\frac{1}{m}ln|1+mx| - x]|_0^x$$

$$\boxed{\begin{aligned} D(x) &= \int_0^x B(x)\ dx = \{\frac{1}{2m^2}\}[\frac{x}{(1\ +\ mx)}] - \frac{1}{m^3}[\ ln|1+mx|\ ] + \{\frac{1}{2m^2}\}\ [x] \\ D(x) &= \int_0^x [\ \int_0^x x\ dx\ ]\ dx = \int_0^x [\frac{1}{2}x^2]\ dx = \frac{1}{6}x^3|_0^x = \frac{1}{6}x^3 \end{aligned}}$$

Specializing tapered cross section coefficients A, B, C, D, and FEM values to constant cross section values:

$$A = L, B = C = \frac{1}{2}L^2, D = \frac{1}{6}L^3$$

$$V_A = \frac{1}{(-BC + AD)}\{-A\,[v_A - v_B\,] + [(C - A\,L)\,\theta_A - C\,\theta_B\,] + [C - A\,(L-a)\,]\,\}\,EI_1$$

$$-\frac{A}{(-BC+AD)} = -\frac{L}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = -\frac{L}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{12}{L^3}$$

$$\frac{C - A\,L}{(-BC+AD)} = \frac{\frac{1}{2}L^2 - (L)\,L}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = -\frac{-\frac{1}{2}L^2}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = -\frac{6}{L^2}$$

$$-\frac{C}{(-BC+AD)} = -\frac{\frac{1}{2}L^2}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = -\frac{\frac{1}{2}L^2}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{6}{L^2}$$

$$\frac{C - A\,(L-a)}{(-BC+AD)} = \frac{\frac{1}{2}L^2 - (L)\,(L-a)}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = \frac{-\frac{1}{2}L^2 + La}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{6}{L^2} - \frac{12a}{L^3}$$

$$M_A = \frac{1}{(-BC + AD)}\{-B\,[v_A - v_B\,] + [(D - BL)\,\theta_A - D\,\theta_B\,] + [D - B\,(L-a)\,]\,\}\,EI_1$$

$$-\frac{B}{(-BC+AD)} = -\frac{\frac{1}{2}L^2}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = -\frac{\frac{1}{2}L^2}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{6}{L^2}$$

$$\frac{D - B\,L}{(-BC+AD)} = \frac{\frac{1}{6}L^3 - (\frac{1}{2}L^2)\,L}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = -\frac{-\frac{1}{3}L^3}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{4}{L}$$

$$-\frac{D}{(-BC+AD)} = -\frac{\frac{1}{6}L^3}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = -\frac{\frac{1}{6}L^3}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{2}{L}$$

$$\frac{D - B\,(L-a)}{(-BC+AD)} = \frac{\frac{1}{6}L^3 - (\frac{1}{2}L^2)\,(L-a)}{-(\frac{1}{2}L^2)\,(\frac{1}{2}L^2) + (L)\,(\frac{1}{6}L^3)} = \frac{-\frac{1}{3}L^3 + \frac{1}{2}L^2 a}{-\frac{1}{4}L^4 + \frac{1}{6}L^4} = \frac{4}{L} - \frac{6a}{L^2}$$

$IL\ FEM$:

$$\frac{(C\,L - D) + (B - A\,L)(L-a)}{-BC + AD} = \frac{\{\,\frac{1}{2}L^2(L) - \frac{1}{6}L^3\,\} + \{\,\frac{1}{2}L^2 - (L)\,L\,\}\,(L-a)}{\frac{1}{6}L^4 - \frac{1}{4}L^4}$$

$$\frac{(C\,L - D) + (B - A\,L)(L-a)}{-BC + AD} = \frac{\frac{1}{2}L^3 - \frac{1}{6}L^3 - (\frac{1}{2}L^2)(L-a)}{-\frac{1}{12}L^4} = \frac{\frac{1}{2}L^3 - \frac{1}{6}L^3 - \frac{1}{2}L^3 + \frac{1}{2}L^2\,a}{-\frac{1}{12}L^4}$$

$$\frac{(C\,L - D) + (B - A\,L)(L-a)}{-BC + AD} = \frac{-\frac{1}{6}\,L^3 + \frac{1}{2}L^2\,a}{-\frac{1}{12}L^4} = \frac{2}{L} - \frac{6a}{L^2}$$

Appendix G

Integrals Table

$\int_a^b \frac{1}{[1+mx]^3}\,dx$

$$\int_a^b (1+mx)^{-3}\,dx = \frac{1}{m}\int_a^b m\,(1+mx)^{-3}\,dx = \frac{1}{m}\frac{1}{(-2)}(1+mx)^{-2}|_a^b$$

$$\boxed{\int_a^b \frac{1}{[1\ +\ mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{1}{[1\ +\ mx]^2}]\ |_a^b}$$

$$\boxed{\int_0^x \frac{1}{[1\ +\ mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{1}{[1\ +\ mx]^2} - 1]}$$

$\int_a^b \frac{x}{[1+mx]^3}\,dx$

$$\int_a^b (x)\,(1+mx)^{-3}d\,x = -\frac{1}{2m}[\frac{x}{(1+mx)^2}]|_a^b - [-\frac{1}{2m}\int_a^b \frac{1}{(1+mx)^2}\,dx\,]$$

$$u = x \quad \rightarrow \quad du = dx$$

$$dv = (1\ +\ mx)^{-3}dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-2)}(1+mx)^{-2} = -\frac{1}{2m}\frac{1}{(1+mx)^2}$$

$$\int_a^b \frac{1}{(1\ +\ mx)^2}\,dx = \frac{1}{m}\frac{1}{(-1)}(1+mx)^{-1}|_a^b$$

$$\int_a^b (x)\,(1+mx)^{-3}\,dx = -\frac{1}{2m}[\frac{x}{(1+mx)^2}]|_a^b + \frac{1}{2m}[\frac{1}{m}\frac{1}{(-1)}(1+mx)^{-1}\,]|_a^b$$

$$\int_a^b (x)\,(1+mx)^{-3}\,dx = -\{\frac{1}{2m}\}[\frac{x}{(1+mx)^2}]|_a^b - \{\frac{1}{2m^2}\}[\frac{1}{(1+mx)}]|_a^b$$

$$\boxed{\int_a^b \frac{x}{[1\ +\ mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{x}{[1\ +\ mx]^2}]|_a^b - \{\frac{1}{2m^2}\}[\frac{1}{[1\ +\ mx]}]|_a^b}$$

$$\boxed{\int_0^x \frac{x}{[1\ +\ mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{x}{[1\ +\ mx]^2}] - \{\frac{1}{2m^2}\}[\frac{1}{[1\ +\ mx]} - 1]}$$

$\int_a^b \frac{x^2}{[1+mx]^3}\,dx$

$\int_a^b \{x^2\}\,\{\frac{1}{(1+mx)^3}\}\;dx = -\frac{1}{2m}\,[\frac{x^2}{(1+mx)^2}]|_a^b - [-\frac{1}{2m}\int_a^b \frac{2x}{(1+mx)^2}\,dx\,]$

$u = x^2 \quad \rightarrow \quad du = 2x\,dx$

$dv = (1+mx)^{-3}dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-2)}(1+mx)^{-2} = -\frac{1}{2m}\frac{1}{(1+mx)^2}$

$\int_a^b \frac{x}{(1+mx)^2}\,dx = -\frac{1}{m}\,[\frac{x}{(1+mx)}]|_a^b - [-\frac{1}{m}\int_a^b \frac{1}{(1+mx)}\,dx\,]$

$u = x \quad \rightarrow \quad du = dx$

$dv = (1+mx)^{-2}dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-1)}(1+mx)^{-1} = -\frac{1}{m}\frac{1}{(1+mx)}$

$$\int_a^b \frac{1}{(1\;+\;mx)}\,dx = \frac{1}{m}\,[\;ln|1+mx|\;]|_a^b$$

$\int_a^b \{x^2\}\,\{\frac{1}{(1+mx)^3}\}\;dx = -\frac{1}{2m}\,[\frac{x^2}{(1+mx)^2}]|_a^b + \frac{1}{m}\,[-\frac{1}{m}\,[\frac{x}{(1+mx)}]|_a^b + \frac{1}{m}\,[\frac{1}{m}\,ln|1+mx|\;|_a^b\;]\;]$

$\int_a^b \{x^2\}\,\{\frac{1}{(1+mx)^3}\}\,dx = -\{\frac{1}{2m}\}[\frac{x^2}{(1+mx)^2}]|_a^b - \{\frac{1}{m^2}\}[\frac{x}{(1+mx)}]|_a^b + \{\frac{1}{m^3}\}\;[ln|1+mx|]|_a^b$

$$\boxed{\int_a^b \frac{x^2}{[1\;+\;mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{x^2}{[1\;+\;mx]^2}]|_a^b - \{\frac{1}{m^2}\}[\frac{x}{[1\;+\;mx]}]|_a^b + \{\frac{1}{m^3}\}[ln|1+mx|]|_a^b}$$

$$\boxed{\int_0^x \frac{x^2}{[1\;+\;mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{x^2}{[1\;+\;mx]^2}] - \{\frac{1}{m^2}\}[\frac{x}{[1\;+\;mx]}] + \{\frac{1}{m^3}\}[ln|1+mx|]}$$

$$\int_a^b \frac{x^3}{[1+mx]^3}\,dx$$

$$\int_a^b \{x^3\}\{\frac{1}{(1+mx)^3}\}\ dx = -\frac{1}{2m}[\frac{x^3}{(1+mx)^2}]|_a^b - [-\frac{1}{2m}\int_a^b \quad \frac{3x^2}{(1+mx)^2}\,dx\ ]$$

$u = x^3 \quad \rightarrow \quad du = 3x^2 dx$

$dv = (1+mx)^{-3}dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-2)}(1+mx)^{-2} = -\frac{1}{2m}\frac{1}{(1+mx)^2}$

$$\int_a^b \frac{x^2}{(1+mx)^2}\,dx = -\frac{1}{m}[\frac{x^2}{(1+mx)}]|_a^b - [-\frac{1}{m}\int_a^b \frac{2x}{(1+mx)}\,dx\ ]$$

$u = x^2 \quad \rightarrow \quad du = 2x\,dx$

$dv = (1+mx)^{-2}dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-1)}(1+mx)^{-1} = -\frac{1}{m}\frac{1}{(1+mx)}$

$$\int_a^b \frac{x}{(1\ +\ mx)}\,dx = \frac{1}{m}[\ x\,ln|1+mx|\ ]|_a^b - [\ \frac{1}{m}\int_a^b ln|1+mx|\,dx\ ]$$

$u = x \quad \rightarrow \quad du = dx$

$dv = (1+mx)^{-1}dx \quad \rightarrow \quad v = \frac{1}{m}ln|1+mx|$

$$\int_a^b ln|1+mx|\,dx = [\frac{1}{m}ln|1+mx| + x\,ln|1+mx| - x\,]|_a^b$$

$$\int_a^b \frac{x}{(1\ +\ mx)}\,dx = \frac{1}{m}\int_a^b \frac{(1\ +\ mx\ -\ 1)}{(1\ +\ mx)}\,d\,x = \frac{1}{m}\int_a^b [\frac{(1\ +\ mx)}{(1\ +\ mx)} - \frac{1}{(1\ +\ mx)}]\,dx$$

$$\int_a^b \frac{x}{(1\ +\ mx)}\,dx = \frac{1}{m}[x - \frac{1}{m}ln|1+mx|]|_a^b$$

$$\int_a^b \{x^3\}\{\frac{1}{(1\ +\ mx)^3}\}\ dx$$

$$= -\frac{1}{2m}[\frac{x^3}{(1\ +\ mx)^2}]|_a^b + \frac{3}{2m}[-\frac{1}{m}[\frac{x^2}{(1\ +\ mx)}]|_a^b + \frac{2}{m}[\frac{1}{m}[x - \frac{1}{m}ln|1+mx|\ ]|_a^b\ ]\ ]$$

$$\int_a^b \{x^3\}\{\frac{1}{(1\ +\ mx)^3}\}\ dx$$

$$= -\frac{1}{2m}[\frac{x^3}{(1\ +\ mx)^2}]|_a^b - \frac{3}{2m^2}[\frac{x^2}{(1\ +\ mx)}]|_a^b + \frac{3}{m^3}[x]|_a^b - \frac{3}{m^4}[ln|1+mx|]|_a^b$$

$$\boxed{\int_a^b \frac{x^3}{[1\ +\ mx]^3}\,dx = -\frac{1}{2m}[\frac{x^3}{[1\ +\ mx]^2}]|_a^b - \frac{3}{2m^2}[\frac{x^2}{[1\ +\ mx]}]|_a^b + \frac{3}{m^3}[x]|_a^b - \frac{3}{m^4}[ln|1+mx|]|_a^b}$$

$$\boxed{\int_0^x \frac{x^3}{[1\ +\ mx]^3}\,dx = -\{\frac{1}{2m}\}[\frac{x^3}{[1\ +\ mx]^2}] - \{\frac{3}{2m^2}\}[\frac{x^2}{[1\ +\ mx]}] + \{\frac{3}{m^3}\}[x] - \{\frac{3}{m^4}\}[ln|1+mx|]}$$

$\int_a^b \frac{x^4}{[1 + mx]^3} dx$

$$\int_a^b \{x^4\}\{\frac{1}{(1 + mx)^3}\} dx = -\frac{1}{2m}[\frac{x^4}{(1 + mx)^2}]|_a^b - [-\frac{1}{2m}\int_a^b \frac{4x^3}{(1 + mx)^2} dx]$$

$u = x^4 \quad \rightarrow \quad du = 4x^3 dx$

$dv = (1 + mx)^{-3} dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-2)}(1 + mx)^{-2} = -\frac{1}{2m}\frac{1}{(1 + mx)^2}$

$$\int_a^b \frac{x^3}{(1 + mx)^2} dx = -\frac{1}{m}[\frac{x^3}{(1 + mx)}]|_a^b - [-\frac{1}{m}\int_a^b \frac{3x^2}{(1 + mx)} dx]$$

$u = x^3 \quad \rightarrow \quad du = 3x^2 dx$

$dv = (1 + mx)^{-2} dx \quad \rightarrow \quad v = \frac{1}{m}\frac{1}{(-1)}(1 + mx)^{-1} = -\frac{1}{m}\frac{1}{(1 + mx)}$

$$\int_a^b \frac{x^2}{(1 + mx)} dx = \frac{1}{m}[x^2 \, ln|1 + mx|]|_a^b - [\frac{1}{m}\int_a^b 2x \, ln|1 + mx| \; dx]$$

$u = x^2 \quad \rightarrow \quad du = 2x dx$

$dv = (1 + mx)^{-1} dx \quad \rightarrow \quad v = \frac{1}{m} ln|1 + mx|$

$$\int_a^b x \, ln|1 + mx| \; dx = x[\frac{1}{m} ln|1 + mx| + x \, ln|1 + mx| - x]$$

$$-[\int_a^b \{\frac{1}{m} ln|1 + mx| + x \, ln|1 + mx| - x\} \; dx]$$

$u = x \quad \rightarrow \quad du = dx$

$dv = ln|1 + mx| \, dx \quad \rightarrow \quad v = \frac{1}{m} ln|1 + mx| + x \, ln|1 + mx| - x$

$$\int_a^b \frac{x^2}{(1 + mx)} dx = \frac{1}{m^2}\int_a^b \frac{(m^2x^2 + 2mx + 1 - 2mx - 2 + 1)}{(1 + mx)} dx$$

$$\int_a^b \frac{x^2}{(1 + mx)} dx = \frac{1}{m^2}\int_a^b [\frac{(1 + mx)^2}{(1 + mx)} - \frac{2(1 + mx)}{(1 + mx)} + \frac{1}{(1 + mx)}] dx$$

$$\int_a^b \frac{x^2}{(1 + mx)} dx = \frac{1}{m^2}[x + \frac{1}{2}mx^2 - 2x + \frac{1}{m} ln|1 + mx| \,]|_a^b$$

$$\int_a^b \frac{x^2}{(1 + mx)} dx = \frac{1}{m^2}[\frac{1}{2}mx^2 - x + \frac{1}{m} ln|1 + mx| \,]|_a^b$$

$$\int_a^b \{x^4\}\{\frac{1}{(1 + mx)^3}\} dx$$

$$= -\frac{1}{2m}[\frac{x^4}{(1 + mx)^2}]|_a^b + \frac{2}{m}[-\frac{1}{m}[\frac{x^3}{(1 + mx)}]|_a^b + \frac{3}{m}[\frac{1}{m^2}[\frac{1}{2}mx^2 - x + \frac{1}{m} ln|1 + mx| \,]|_a^b \,]\,]$$

$$\int_a^b \{x^4\}\{\frac{1}{(1 + mx)^3}\} dx = -\frac{1}{2m}[\frac{x^4}{(1 + mx)^2}]|_a^b - \frac{2}{m^2}[\frac{x^3}{(1 + mx)}]|_a^b + \frac{6}{m^4}[\frac{1}{2}mx^2 - x + \frac{1}{m} ln|1 + mx| \,]|_a^b$$

$$\boxed{\int_a^b \frac{x^4}{[1 + mx]^3} dx = -\frac{1}{2m}[\frac{x^4}{[1 + mx]^2}]|_a^b - \frac{2}{m^2}[\frac{x^3}{[1 + mx]}]|_a^b + \frac{3}{m^3}[x^2]|_a^b - \frac{6}{m^4}[x]|_a^b + \frac{6}{m^5}[ln|1 + mx| \,]|_a^b}$$

$$\boxed{\int_0^x \frac{x^4}{[1 + mx]^3} dx = -\frac{1}{2m}[\frac{x^4}{[1 + mx]^2}] - \frac{2}{m^2}[\frac{x^3}{[1 + mx]}] + \frac{3}{m^3}[x^2] - \frac{6}{m^4}[x] + \frac{6}{m^5}[ln|1 + mx| \,]}$$