Texas
Department
of Transportation

Bridge Load Rating Spreadsheets

Version 03202024

User Guide

Texas Department of Transportation

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Disclaimer

This suite of visual basis enhanced spreadsheets should not be relied upon without the benefit of the judgment of an engineer familiar with the principles of structural analysis and load rating. Accordingly, the results of each analysis must be reviewed and sealed by a licensed professional engineer. An engineer's judgment is needed to recognize special situations where the routine, simplified procedures of this load rating tool are inadequate. In addition, an engineer may be called upon to make decisions about the strength of materials, the accuracy of field reports, the stability of beams and supports, and the need for additional field investigations.

No expressed or implied warranties are made by the Texas Department of Transportation (Department) for the accuracy, completeness, reliability, usability, or suitability of the program-associated data or documentation. The Department assumes no responsibility for incorrect results or damages resulting from the use of this suite of visual basis enhanced spreadsheets.

General Information

Bridge Inspection Database

To meet the National Bridge Inspection Standards (NBIS) required by the Federal Highway Administration (FHWA), the Texas Department of Transportation (TxDOT) maintains a bridge inspection information database covering all on-system and off-system bridges in Texas. Among the data maintained is the inventory and operating rating for each bridge.

The inventory rating is indicative of the heaviest loads that can use the bridge for an indefinite period of time. The operating rating represents the maximum live load to which the structure may be safely subjected. These ratings are dependent on the weight and configuration of the rating vehicle and the load rating method. Historically there have been two vehicle configurations and two rating methods used in Texas bridges: H or HS allowable stress rating and H or HS load factor rating. TxDOT is presently under an FHWA mandate to use HS, SHV and EV load factor ratings in the database, and RATE is also in compliance with the upcoming SNBI requirement to report AASHTO Type 3 trucks and Notional Rating Load (NRL) load factor ratings. Thus, rating factors are generated for three AASHTO Type 3 trucks: Type 3, Type 3S2, and Type 3-3, as defined in Section 6 of The Manual for Bridge Evaluation (MBE), the Notional Rating Load as defined in Section 6 of the MBE, four Specialized Hauling Vehicles (SHVs) load rating trucks: SU4, SU5, SU6 and SU7, as defined in Section 6 of the MBE, and two Emergency Vehicles (EVs) as defined in the Fixing America Surface Transportation Act (FAST Act) (Pub.L.114-94) in the spreadsheet. ***At this time, the spreadsheets cannot be used to calculate Load and Resistance Factor Rating (LRFR) using the HL-93 notional load.***

Bridge Load Rating Capabilities

The Bridge Rating Spreadsheets suite is used to calculate flexural load factor ratings of the superstructure for five different bridge types:

1. T-beam (slab and girder) simple span;
2. Pan girder simple span;
3. Slab simple span;
4. Prestressed beam simple span; and
5. Steel stringer simple span.

Please note that the analyses performed by these spreadsheets assume simply supported spans, and shear ratings are not checked.

Since the spreadsheets are intended for load rating superstructures based on the as-built structural details, the plans must be available or accurate measurements should be made of the required dimensions. Additionally, all load ratings should consider any structural deterioration that would affect the flexural load carrying capacity of the structure. Because the load ratings are performed at or near mid-span, only deterioration attributable to the mid-span region can be considered.

Controlling Element in Bridge Rating

The superstructure of a bridge normally controls the load rating for the structure because it typically has a smaller factor of safety than the substructure or the foundations of a bridge. Also, flexure rather than shear usually controls the load ratings of bridge superstructures.

Judgment must be exercised when making these assumptions to ensure they are proper assumptions for the structure being load rated. For example, when a significant amount of deterioration is present in the substructure or foundation elements of a bridge, these elements must also be load rated (using other load rating tools). When structures have been widened, the original portion of the structure and each widening should be rated separately to determine which controls the load rating of the structure. Typically, but not always, the oldest section (the original structure) will control. Multiple ratings must be performed to determine the controlling span when a structure has more than one span type (i.e., pan girders and prestressed beams), more than one span length, or more than one beam spacing in two or more spans. If multiple load ratings are performed on a structure, a record of each should be retained in the load rating documentation.

Standard Designs

Some bridge plans designate on the layout the standards used to build the bridge (for example, G-18-28-40 is a T-Beam standard); however, the standard details (a.k.a. the standard designs, or simply the standards) themselves may not be included in the plan set. In this case, the standards used to build the bridge may be located by date of construction and the standards designation(s). The Standards Branch of the Bridge Division can assist users in locating the standards sheet(s). Many of these have been electronically scanned and are stored in a General Services Division (GSD) database archive titled *Bridge Standards Prior to 1980s*, accessible within the Department's Intranet. Certain standard designs for Pan Girder and Slab (FS Slabs only) may be selected and all the data needed to perform the load rating loaded into the input fields of the spreadsheet via a Get Stnd Data button.

System Requirements

Microsoft Excel 97 for Windows 95 or Windows NT 4.0 or better is required to use the Rate Spreadsheet.

Spreadsheet Tabs, Sections, and Input Fields

Spreadsheet Tabs

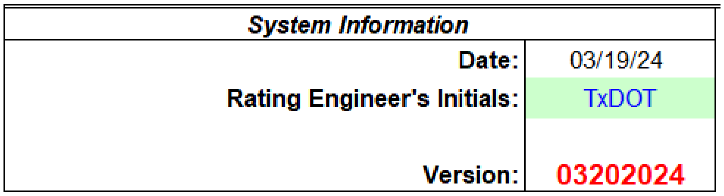
To begin data entry, select the tab at the bottom of the suite of spreadsheets that corresponds to the type of superstructure to be rated. The tabs are labeled T-Beam, Pan Girder, Slab, Prestressed Beam, and Steel Stringer. Clicking on a tab reveals a worksheet (spreadsheet) that is divided into various sections. Green shaded areas within the various sections are input fields whose associated names are shown in the text of this user guide as bold text with brackets. None of the input fields are case-sensitive.

Sections and Input Fields

Each spreadsheet (worksheet) of the suite is broken into various sections. These sections include System Information, Bridge Information, and Structural Data, among others. Each of these three sections has various input fields. In the case of the Prestressed Beam and Flat Slab Bridge Rating sheets the input section data labels and, for the Prestressed Beam, the input fields may change, depending upon user selections and/or the results of internal calculations.

System Information

The System Information section of each worksheet (spreadsheet) is used to enter miscellaneous information about the rating. Initials of the engineer performing the rating (the user) should be entered in the **[Rating Engineer's Initials]** field. This section also displays the current **[Date]** (assumed to be the date on which the calculations were performed) and the current version of the *Bridge Load Rating Spreadsheets*. For a rating date other than the current date, the **[Additional Notes]** field at the bottom of the page may be used. Figure 1 shows an example of a completed System Information section.



System Information

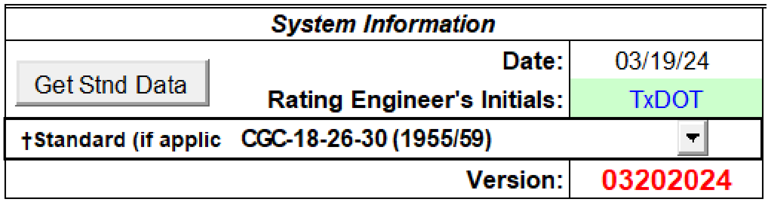
Date: 03/19/24

Rating Engineer's Initials: TxDOT

Version: 03202024

Figure 1. System Information

The content and layout of the System Information section of the Pan Girder and Slab spreadsheets (worksheets) vary from that shown in Figure 1. For these two bridge types previously calculated ratings along with identifying information about the standard are listed in two tables under the Standards Data tab. The input data corresponding to each standard bridge is stored in tables within the respective load rating spreadsheets to be retrieved by the user, as described below, for the user to examine and make any needed modifications for the bridge being load rated. This data can be loaded automatically into the respective input fields. If a standard bridge plan set (hereafter simply "standard") is used that is listed on the Standards Data worksheet (spreadsheet), the standard can be selected from a pull-down menu. To load the standard's data into the input fields, the user clicks on the 'Get Stnd Data' button. Figure 2 shows an example of a System Information section in which a standard has been selected.



System Information

Date: 03/19/24

Rating Engineer's Initials: TxDOT

†Standard (if applic CGC-18-26-30 (1955/59)

Version: 03202024

Figure 2. Standard Code Example.

It is important to note that several assumptions were made when the specific standard data was recorded. The user should carefully review the data retrieved and the available information about the bridge to verify that the input data is reasonable, making modifications as warranted.

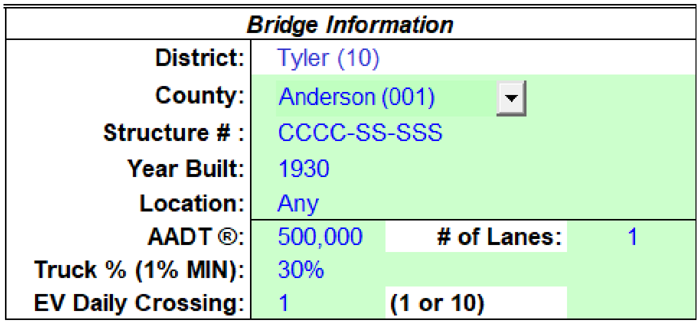
Bridge Information

This section is common to all load rating worksheets (spreadsheets). It contains specific information about the district and county where the bridge is located, the control-section-structure (CSS) number of the bridge, the year the structure was built, and an abbreviated description of the physical location of the bridge. It also contains input fields to record information about traffic conditions such as Annual Average Daily Traffic **[AADT]**, **[Truck Percentage],** and **[EV Daily Crossing]**, all of which are needed to rate for emergency vehicles (EVs).

A list of Texas counties is found in a drop-down menu. When a county is selected from the **[County]** field, the corresponding district will appear in the **[District]** field. The **[Year Built]** is used to display recommended material strength recommendations base on the AASHTO *Manual for Condition Evaluation of Bridges, 1994* (*MCEB*) and on the 1982, 1993, 1994, and 2004 editions of Texas' *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges* (*Texas Standard Specifications*). See Appendix A of the *MCEB* and the various items of each edition of the *Texas Standard Specifications* to verify the recommended values and see the plan sheets of the bridge being rated for design or as-built values to input into data fields.

One input line is provided for **[Location]**, to describe the location of the bridge. The only restriction on data input to this line is that the text remains within the borders of the field to be printed properly. The facility (highway designation) and feature crossed should be included in the **[Location]** description. Figure 3 shows an example of a completed Bridge Information field.

AADT and Truck Percentage can be found on the Transportation Planning Map on the TxDOT website: https://www.txdot.gov/inside-txdot/division/transportation-planning/maps.html, and Item 29 and Item 109 on AssetWise. Input either 1 or 10 for EV Daily Crossing. The selection of 10 EV crossings per day would be appropriate in densely populated urban regions, while assuming 1 EV crossing per day would be reasonable in rural areas. 10 EV crossing per day is recommended when the AADT is more than 5000, but proximity to nearby fire stations shall also be considered when determining the EV crossing frequency. **[# of Lanes]** is the number of trucks (lanes) that can be placed along the bridge width.



Bridge Information

District:	Tyler (10)		
County:	Anderson (001)		
Structure # :	CCCC-SS-SSS		
Year Built:	1930		
Location:	Any		
AADT ®:	500,000	**# of Lanes:**	1
Truck % (1% MIN):	30%		
EV Daily Crossing:	1	**(1 or 10)**	

Figure 3. Bridge Information.

Structural Data Input Tables

These tables are for input of the main load carrying member information needed by each spreadsheet to determine dead load moments and the moment capacity for the specified beam or slab. Diagrams have been included to aid in understanding certain dimensions.

- Below are field definitions common to most of the bridge load rating program sheets:

[Overlay] (inches) – the depth of asphalt, or ACP, on the deck or slab. This value to input is best determined from a field inspection.

[Misc. Non-Comp. Dead Load] (k/ft) – any load added to the beam prior to the beam being made composite with the bridge deck (e.g. the weight of haunches and/or the weight of diaphragms not otherwise accounted for in the analysis).

[Year Built] – the year construction of the bridge began. The spreadsheet displays recommendations of material strengths based on this entry. This information should be used if design or as-built materials strengths are not known. F_y is yield strength, in ksi, of steel.

[Specified Compressive Strength] (ksi) – (shown as f'_c,) typically varies according to the year built. Texas Class "A" concrete has had an f'_c of 3 ksi since the mid 1930's. However, for bridges built before 1959 that were <u>not</u> built by TxDOT and for which strength data is not available, an f'_c, of 2.5 ksi is more appropriate.

- Below are input data field definitions specific to the following bridge types:

T-Beam (slab and girder), simple span;

Pan Girder, simple span;

Slab, simple span;

Prestressed Beam, simple span; and

Steel Stringer, simple span.

T-Beam

[Overall Span] (ft) is the total length center-to-center of bents of the simply-supported T-beam. This is not the total structure length.

[Slab Thickness] (inches) is the thickness of the slab being supported by the beams (see Figure 4). If the thickness changes from beam to beam, use engineering judgment to choose an appropriate nominal thickness.

[Beam Spacing] (ft) is based on the perpendicular distance between the centerline of the beam being load rated to centerlines of adjacent beams. This establishes the amount of slab supported by the beam and is used to calculate the distribution of the live load. If distances to adjacent beams differ, use engineering judgment when specifying the beam spacing. Note that with one exception the live load distribution factors are calculated in accordance with the *Standard Specifications for Highway Bridges*, 11th Edition (2002) [4]. The exception only applies to the Prestressed Beam worksheet when the user selects "non-std" from the beam type pull down list and chooses to input the distribution factor manually.

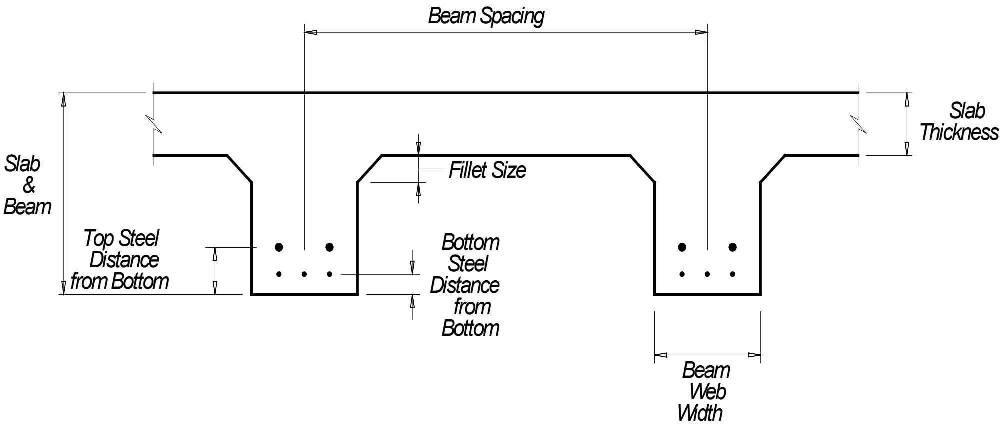


Figure 4. T-Beam Diagram.

[Slab Plus Beam Depth] is the distance, in inches, from the top of the slab to the bottom of the T-beam. The **[Beam Web Width]** is the width, in inches, of the stem of the "T". This information is used to determine the correct slab and beam weight for the dead load moment and to help determine the load carrying capacity of the beam.

[Misc. Dead Load per Beam], in kips per ft., includes railing, sidewalks, medians and curbs distributed to the beam being rated using engineering judgment. In the case of T-Beam bridges these loads are that portion of any dead load (beyond the dead load of the beam) that can be apportioned to the beam. For simplicity, this number may be calculated by taking the total miscellaneous dead load for the entire span, in kips, and dividing by the total length, in feet, of all beams in the span (the product of the number of beams and the length of the beams). For example, if there are five 35-ft T-beams supporting 5.25 kips of miscellaneous dead load, the value placed in the field is 5.25 kips/(5*35-ft.) = 0.03 k/ft. The load rating engineer is free to calculate this input value according to his or her own judgement.

[Total Area of Steel], in square inches, refers to the reinforcing steel running longitudinally within the T-beam. The depth of this steel measured from the center of the bars in inches, is noted in the **[Distance from Bottom]** field. The spreadsheet allows for the input of two layers of steel. If the bridge being rated has more than two layers, the bottom layer area and distance should be entered in the fields for the bottom layer and the remaining reinforcement should be entered in the fields for the top layer using the remaining area and distance from the bottom of the beam to the centroid of that remaining reinforcement.

[Span Bearing Length Deduction] is the portion, in feet, of the overall bridge span located at each end of the span that is between the centerline of the bearing and the centerline of the bent (see Figure 13). The value to be entered for **[Span Bearing Length Deduction]** is the sum of these two described end portions of the beam. This distance is measured along the centerline of the beam.

The spreadsheet subtracts this sum from the value entered in **[Overall Span]** to determine the effective flexural length of the beam.

[Fillet Size], in inches, is the perpendicular dimension of the typically 45° sloped connection between the slab and the beam.

Pan Girder

If a Standard Code is used to load information for a ***Pan Girder*** bridge, all fields in the *User Structural Data Input Table A* and *User Structural Data Input Table B* of the spreadsheet will be automatically filled in. See the **System Information** section above for a detailed description of how to use Standard Codes. Remember that subsequent modification of the retrieved data may be required when known structural data differs from the standard data retrieved.

[Overall Span] is the total length, in feet, center-to-center of bents of the simply-supported pan girder. This is not the total load rating span length. Do not deduct the bearing distance when determining **[Overall Span]** as this is handled in the calculations using **[Span Bearing Length Deduction]**.

[Beam plus Slab Depth] is the distance from the top of slab to the bottom of the beam. For pan girder bridges, this dimension is always 24 or 33 inches for span lengths of 30'-4" and 40', respectively.

[Misc. Dead Load per Beam], in kips per ft., includes railing, sidewalks, medians and curbs that are distributed to the beam being rated using engineering judgment. In the case of T-Beam bridges these loads are that portion of any dead load (beyond the dead load of the beam) that can be apportioned to the beam. For simplicity, this number may be calculated by taking the total miscellaneous dead load for the entire span, in kips, and dividing it by the total length, in feet, of all pan girders on the entire span (the product of the number of beams and the length of the beams). For example, if there are five 40-ft. Pan Girder beams supporting 15 kips of miscellaneous dead load, the value placed in the field is 15 kips/(5*40-ft.) = 0.075 k/ft.

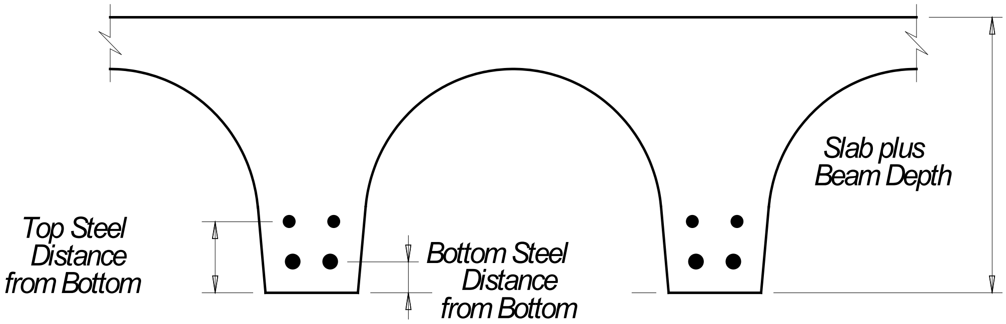


Figure 5. Pan Girder.

[Total Area of Steel], in square inches, refers to the reinforcing steel running longitudinally within the T-beam. The depth of this steel measured from the center of the bars in inches, is noted in the **[Distance from Bottom]** field. The spreadsheet allows for the input of two layers of steel. If the bridge being rated has more than two layers, the bottom layer area and distance should be entered in the fields for the bottom layer and the remaining reinforcement should be entered in the fields for the top layer using the remaining area and distance from the bottom of the beam to the centroid of that remaining reinforcement.

[Span Bearing Length Deduction] is derived from each portion, in feet, of the overall bridge span between the centerline of the bearing and the centerline of the bent (see Figure 13). The value to be entered for **[Span Bearing Length Deduction]** is the sum of these two described end portions of the beam. This distance is measured along the centerline of the beam. The spreadsheet subtracts this sum from the value entered in **[Overall Span]** to determine the effective flexural length of the beam.

Flat Slab

There are two types of flat slabs that the ***Flat Slab*** spreadsheet can load rate.

The first is analyzed using the traditional AASHTO strip analysis method detailed in Article 3.24.3.2 of the AASHTO *Standard Specifications for Highway Bridges* (*AASHTO SS*).

The second type is referred to as an FS slab, the design and analysis of which is based on research conducted at the University of Illinois. The findings of this research and resulting design procedures are documented in a series of University of Illinois research bulletins. These included Illinois Bulletin Nos. 314, 315, 332, 369, 386 and 346, with the latter is of use in the analysis of FS slab bridges. FS slab bridges have structural curbs that contribute to the load-carrying capacity, while the *AASHTO SS* concept of flat slab bridges either have no curbs or have non-structural curbs that do not contribute to the load-carrying capacity.

If a Standard Code is used to retrieve load rating input data for a ***Flat Slab*** bridge, all fields in the *User Structural Data Input Table A* and *User Structural Data Input Table B* of the spreadsheet will be automatically filled. See the **System Information** section for a detailed description of how to use Standard Codes. Remember that subsequent modification of the retrieved data may be required when known structural data differs from the standard data retrieved.

[Overall Span along Roadway] is the total length center-to-center of bents, in feet, of the simply-supported slab. This is not the total structure length. This is always measured parallel to the centerline of the roadway, even for skewed bridges.

[Overall Bridge Width], in feet, is measured perpendicular to the roadway centerline for all Flat Slab bridges (see Figure 6).

[Slab Thickness] is the thickness of the slab, in inches.

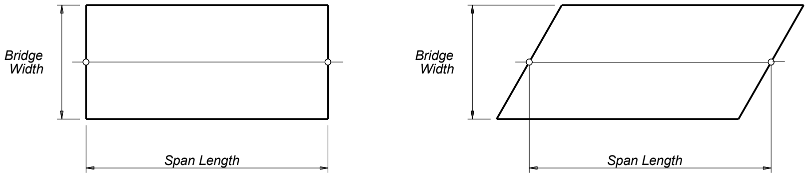


Figure 6. Flat Slab Geometry.

[Skew] is defined as the angle between the line perpendicular to the centerline of the roadway and the centerline of a bent or support. For a majority of flat slab bridges, the bottom steel runs parallel to the centerline of the bridge. However, in flat slab bridges that have a skew greater than 30 degrees, the bottom steel generally runs normal to the supports (See Figure 7).

[Slab Steel Direction] is specified by entering "p" (or "P") for parallel to the roadway or "n" (or "N") for normal to the supports.

[$A_{s\text{-slab}}$, Area of Slab Tension Steel], in square inches per foot, refers to the bottom tension reinforcing steel found within a 1-foot strip. This can be calculated as (12/S) * (bar area), where S equals bar spacing, in inches (see Figure 7)

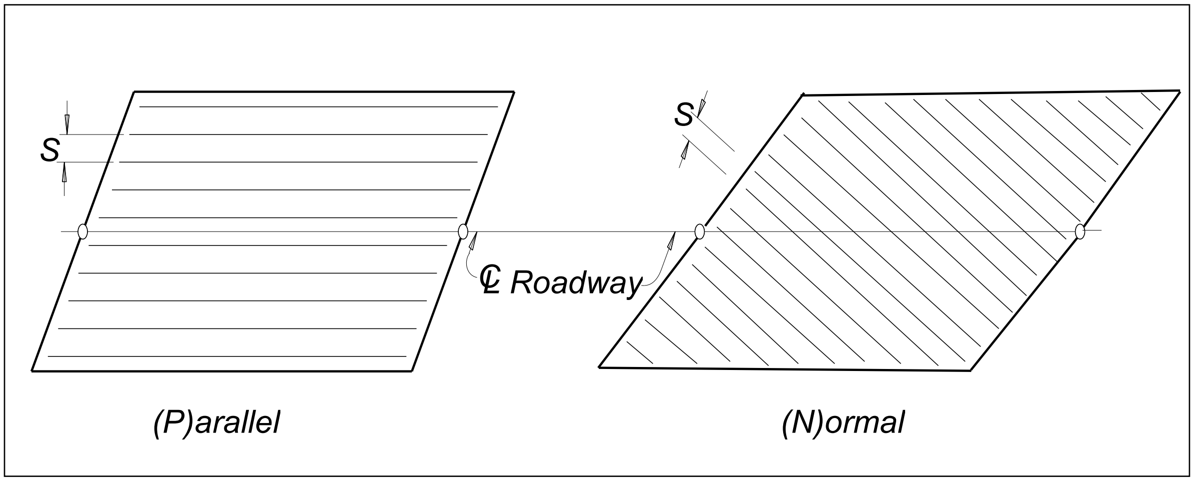


Figure 7. Flat Slab Steel Direction.

Include the contribution of "galloping" bars if they are effective at midspan. The distance to the tension steel from the bottom of the slab is input in the **[Distance to $A_{s\text{-slab}}$ from Bottom of Slab]** field, and is measured to the center of the bars, in inches.

If structural curbs exist on a flat slab bridge, "c" (or "C") should be entered in **[Left Curb, Beam or None]**, at which time additional fields will appear. **[Curb Height above Slab]**, in inches, does not include the slab thickness. **[Top of Curb Width]**, in inches, is shown in Figure 8.

[Bottom of Curb Width], in inches, is measured at the top of the slab. **[Misc. Dead Load on Curb]**, in kips per ft., is for the total dead load carried by curbs on both sides of the slab and includes railing but not curb self-weight, which is calculated automatically by the spreadsheet from the curb dimensions input by the user.

[Area of Curb Tension Steel], in square inches, is the summation of bar areas within the width of the bottom of the curb for bars running parallel with the curb.

[Distance from Bottom of Slab], in inches, is measured from the center of the bars in tension (within the width of the curb) to the bottom of the slab. **[Area of Curb Compression Steel]** is the total area of bars in the top of the curb. **[Distance from Top of Curb]** is from the center of the compression steel to the top of the curb (see Figure 8).

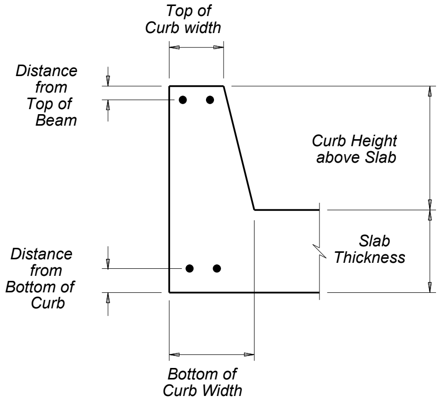


Figure 8. Flat Slab Curbs.

If there are beams below the slab instead of curbs, "b" (or "B") should be entered in the input field for **[Left Curb, Beam or None]**, at which time additional fields will appear. **[Beam Depth Below Slab],** in inches, does not include the slab thickness, and should be entered as the distance that the beam extends beyond the bottom of the curb**. [Bottom of Beam Width]**, in inches, is measured at the bottom surface of the beam. See Figure 9 for the dimensions of a beam. **[Top of Beam Width]**, in inches, is measured at the bottom of the slab. **[Misc. Dead Load on Beam]**, in kips per ft., is for the total dead load carried by beams on both sides (if applicable) and includes railing, but does not include beam self-weight, which is calculated by the program from the beam dimensions input by the user.

[Area of Beam Tension Steel], in square inches, is the summation of bar areas within the width of the bottom of the beam, if the bars run parallel with the beam. **[Distance from Bottom of Beam]**, in inches, is measured from the center of the bars in tension to the bottom of the beam.

If **[Fy-beam]** is not equal to or greater than 33 ksi the note "**PLEASE MAKE Fy-beam >= 33 ksi**" will be displayed next to the input cell for **[Fy-beam]**. An entry in this field is only necessary if **[Fy-beam]** is different from F_y used for rebar in the slab. If it is the same, leave the field blank. The note **"This cell should be empty"** will appear if there is a value in the adjacent field when analyzing an FS slab with beams. Delete any entered value so that this note is not displayed.

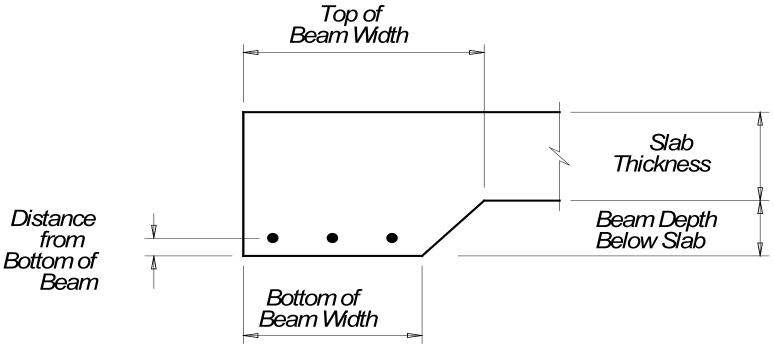


Figure 9. Flat Slab Beams.

If the plans do not show structural curbs or beams, an “n” (or “N”) should be entered next to the input section header, and all other descriptions in the curb/beam section will disappear. If “n” (or “N”) is so entered, any values in the corresponding adjacent input cells will have no effect on the ratings. Such values should be deleted to avoid confusion, but their presence will not affect the calculated load ratings.

[Span Bearing Length Deduction] is the portion of the overall slab span, in feet, located at each end of the slab, that is between the centerline of the bearing and the centerline of the bent (see Figure 13). The value to be entered for **[Span Bearing Length Deduction]** is the sum of these two described end portions of the slab span, measured along the centerline of the roadway. The spreadsheet subtracts this value from **[Overall Span along Roadway]** to calculate the effective flexural length of the slab span.

[**Number of Live Load Lanes]** (1 to 4) is the number of trucks (lanes) that can be placed along the slab width. The Illinois Bulletin No. 346 analytical procedure is limited to wheel lanes of even number from 4 to 8 and thus a flat slab bridge analyze thereby is valid for two, three, or four lanes of traffic, only. For any other number of loaded lanes, the Illinois Bulletin No. 346 analysis is invalid. If a load rating of a flat slab bridge with more than four lanes is required structural curbs or edge beams should not be specified. If no curbs or beams are specified the load rating reverts to an *AASHTO SS* analysis, and the number of lanes entered has no effect on the load rating.

Prestressed I-Beam

[Overall Span] is the total length, in feet, of a simply-supported prestressed beam span. It is not the total structure length.

[Slab Thickness] is the thickness, in inches, of the slab being supported by the beams. If the thickness changes from beam to beam, use engineering judgment to choose an appropriate nominal thickness.

Currently there are eleven prestressed I-Beam Types available to the user—A, B, C, 48, 54, 60, 66, 72, IV, VI and VI(MOD). One type should be selected from the drop-down menu and entered into **[Beam Type]**. The numeric types refer to the depth of that beam in inches. Types A, B, C, IV, VI, and VI(MOD) beams have larger bottom flanges than the numeric types, thus providing more area for additional prestressing strands (see *Table 1*).

Table 1. Prestressed I-Beam Dimensions.

Beam Type	Width – Top Flange, in	Width – Bottom Flange, in	Beam Depth, in	Y_t, in	Y_b, in
A	12	16	28	15.39	12.61
B	12	18	34	19.07	14.93
C	14	22	40	22.91	17.09
48	14	14	48	25.13	22.87
54	16	16	54	28.47	25.53
60	18	18	60	31.59	28.41
66	20	20	66	34.93	31.07
72	22	22	72	38.27	33.73
IV	20	26	54	29.25	24.75
VI	42	28	72	35.60	36.40
VI(MOD)	40	26	72	35.54	36.46

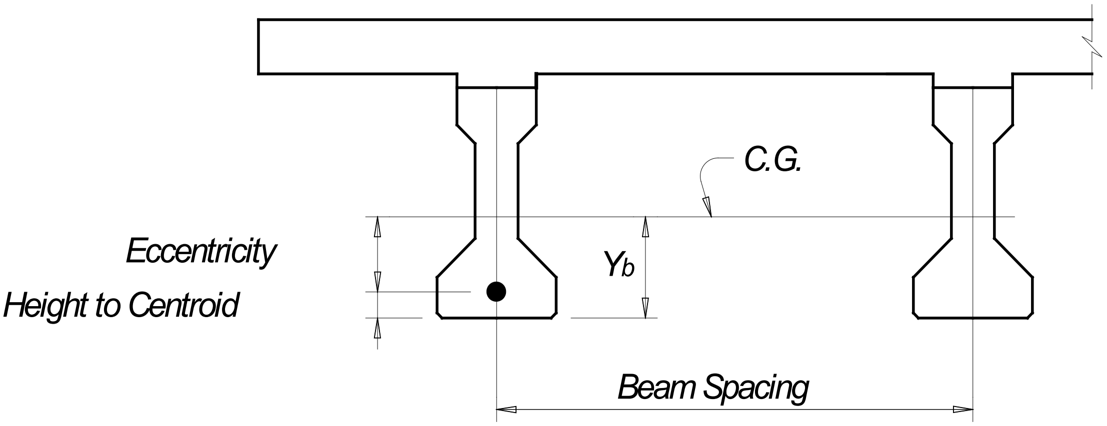


Figure 10. Prestressed I-Beam.

[Beam Spacing] is the perpendicular distance between the centerline of the beam being load rated to centerlines of adjacent beams, in feet. This establishes the amount of slab supported by the beam and is also used to calculate the distribution of the live load. If distances to adjacent beams differ, use engineering judgment to determine the value to enter.

[Number of Strands] refers to the total number of prestressed strands, being the sum of the numbers of straight and any draped strands at mispan. This value may be determined from looking at various plan sheets, standards sheets and/or shop drawings in the final bridge plans. When "as-built" prestressed beam shop plans are available for the bridge, they should be used to determine the strand patterns and concrete strengths.

[Eccentricity at Midspan] is the distance, in inches, between the concrete beam's elastic neutral axis (a.k.a. the center of gravity) and the centroid of the prestressing strands at midspan (see Figure 10). It is affected by the beam type and number of strands. Values for the distance, in inches, from the bottom of the beam to the beam center of gravity, Y_b, and the distance from the top of the beam to the center of gravity, Y_t, are provided in Table 1. When available, use prestressed beam shop drawings to aid in the determination of strand patterns since fabricators often use optional strand patterns that optimize their beam production lines. Shop drawings are usually found in the back of the final bridge plans.

Non-composite dead load moment is influenced by the **[Number of Interior Diaphragms]**, if any. Note that the non-composite dead load due to interior diaphragms is calculated by the spreadsheet. The loading due to interior diaphragms is then added to slab load and any load input as **[Misc. NonComp DL per Beam].** Composite dead loads, including railing, sidewalks, medians, and curbs, must be determined by the user, and input in the **[Misc. Composite DL per Beam]** field, in kips per foot.

[Span Bearing Length Deduction] is the portion, in feet, of the overall bridge span located at each end of the span that is between the centerline of the bearing and the centerline of the bent (see Figure 13). The value to be entered for **[Span Bearing Length Deduction]** is the sum of these two described end portions of the beam. This distance is measured along the centerline of the beam. The spreadsheet subtracts this sum from the value entered in **[Overall Span]** to determine the effective flexural length of the beam.

[Area of Strand] is the area, in square inches, for a single prestressing strand. See final bridge plans or shop drawings for specified prestressing strand size, grade and type. See Table 2 for strand areas for strands of different types and sizes. The value input in **[Strand Type]** is a combination of the type of strand—Stress-Relieved (SR) or Low-Relaxation (LR), and the grade of steel—270, 250, etc.

A typical prestressing strand consists of seven cold-drawn prestressing wires, six of which are wrapped around the seventh, larger wire. After wrapping, SR strands are placed in a continuous heat treatment until the desired mechanical properties have been attained. LR strands are SR strands that have been additionally heated to a "bluing" temperature for a very short period of time while tensioned to a high stress. The additional "bluing" under tension permanently lengthens the strand, reducing the amount of relation that will occur under subsequent long term loading during beam fabrication and service. LR strands have been the industry standard since the early 1980's.

The two typical strand grades are 250 and 270 ksi, indicating the minimum guaranteed ultimate stress (also known as the specified strength). Strand grade may be back-calculated from the specified jacking load shown in the plans or on the shop drawings, if the type of strand is known. According to *AASHTO SS*, Article 9.15.1, the stress in an SR strand in a pretensioned member immediately prior to prestress transfer is $0.70 f'_s$ and in an LR strand is $0.75 f'_s$, where f'_s is the specified strength of the strand. There will be a note on the plans or on the shop drawings that mentions the amount of tension placed on each strand size. For example, a set of plans shows 7/16" diameter strands to be stressed to 18.9 kips. Assume the strand grade to be 250 ksi (SR250). From *Table 2*, we see that 7/16" diameter strands of 250 ksi strength have an **[Area of Strand]** equal to 0.108 in^2. The jacking force for that strand is $0.70\ f'_s = (0.70)[(250\text{ ksi})*(0.108\text{ in}^2)] = 18.9$ kips. This verifies that the Strand Type is SR250 for this 7/16 in. diameter strand, and has an **[Area of Strand]** equal to 0.108 in^2. If the answer does not equal the load in the strands shown on the plans or shop drawings, try another strength (e.g. 270 ksi).

Table 2 Standard Strand Table

Nominal Diameter (in)	Nominal Area (in^2)
GRADE 250	SEVEN-WIRE
5/ 16	0.058
3/8	0.080
7/16	0.108
1/2	0.144
.600	0.216
GRADE 270	SEVEN-WIRE
3/8	0.085
7/16	0.115
1/2	0.153
.600	0.217
GRADE 245	COMPACT
.700	0.346
GRADE 260	COMPACT
.600	0.256
GRADE 270,	COMPACT
1/2	0.174

The compressive concrete strength, f'_c, will differ for the slab and the prestressed beam, and must be input in kips per square inch. Recommended values for **[$f'_{c\text{-}slab}$]**, based on year built, will displayed in the *Recommended Material Properties Table* on the spreadsheet, if a four digit **[Year Built]** value is entered. Texas Class “A” concrete, since the mid-1930’s, has had an f'_c of 3 ksi. However, for slabs built before 1959 that were not built by TxDOT, an f'_c of 2.5 ksi should be used.

The recommended values for **[$f'_{c\text{-}beam}$]**, the final 28 day (design) compressive strength of the beam concrete, and **[$f'_{ci\text{-}beam}$]**, the initial (release) compressive strength of the beam concrete, both in kips per square inch, are displayed as 5 ksi and 4 ksi, respectively, independent of **[Year Built]**. Where concrete strengths are known from the final plans, they should be used in place of the values shown in the *Recommended Material Properties Table*.

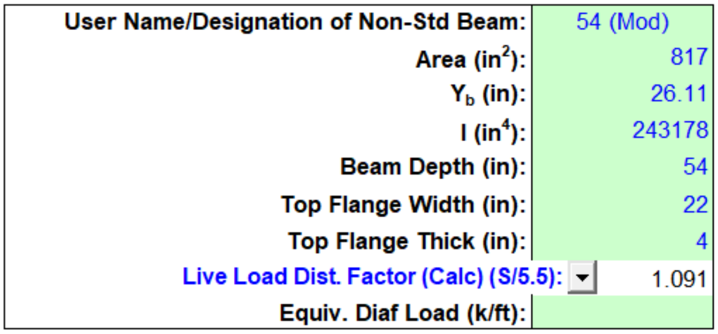
[Slab Embedment], in inches, refers to the distance between the bottom of the slab and the top of the beam. If the beam is embedded into the slab the input value will be positive. If there is a haunch at mid-span of the beam, you may input this haunch as a negative embedment.

[Allowable Tension Factor], x*root(f'_c), where “x” is the value input by the user, is used to determine the allowable tension in the concrete in the bottom fibers of the beam. The square root of the concrete strength, f'_c is multiplied by the input factor, “x”. The allowable concrete tension specified in *MCEB* 6.6.3.3 is 6.0*(square root of f'_c). When the load rating is controlled by the allowable concrete tension, this value directly affects the load rating and therefore the value input must be judiciously chosen sound engineering judgment and in accordance with Department policy. In early versions of this program, this factor was hard coded as 12. Later, the field for user input of this factor was provided and the field contents used to determine the modulus of rupture. For normal strength concrete 7.5 is the multiplier specified in *AASHTO SS*, Article 9.15.2.3 for calculation of cracking stress. The modulus of rupture is used to determine the cracking moment, which previously was the tensile limit for the inventory rating. The cracking moment is no longer used to determine the inventory rating. Rather, the allowable tension in the precompressed tensile zone specified in *AASHTO SS*, Article 9.15.2.2 is to be used as the service level limit for load rating.

Although the user may exercise discretion regarding the **[Allowable Tension Factor]**, no such user discretion is provided with regard to allowable compression stress limits. All the compression stress limits of *AASHTO SS*, Article 9.15.2.2 are strictly enforced by the program calculations.

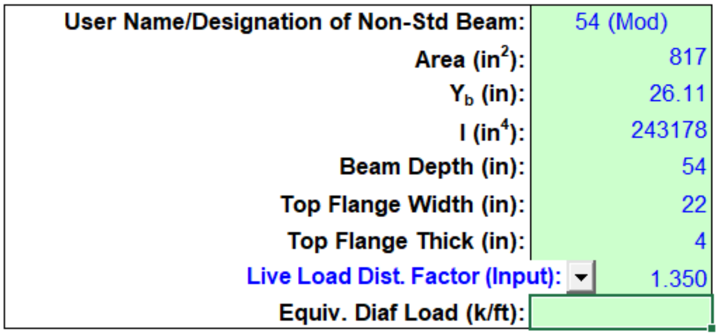
[Loss Calc Method] (LS or CALC) refers to the method used to analyze prestressing losses. According to *AASHTO SS*, Table 9.16.2.2, a prestress loss of 45,000 can be assumed as the Lump Sum (LS) loss of prestress that will occur over the life of a pretensioned beam. To opt for LS losses the user simply selects "LS" for **[Loss Calc Method]**. The user may choose the refined method employing the approximate prestress losses per the calculation procedure of *AASHTO SS*, Article 9.16.2 by selecting CALC for **[Loss Calc Method]**. If there are few strands in the beam, the calculated losses will likely be less than the LS loss, so using CALC will result in a higher service load moment capacity. However, if there are many strands in the beam, the calculated losses will exceed the LS loss and selecting LS will result in the higher service load moment capacity. Selecting LS or CALC will only affect the load rating if it is controlled by allowable stresses rather than strength. After the appropriate data has been entered in each input field, select **"*Click to Converge Calculated Losses*"**. This button executes a procedure which converges the loss calculations. If any input is changed after clicking this button, it must be clicked again to repeat the convergence procedure. Convergence is only efficacious when the CALC method is used and the load rating is controlled by allowable stresses.

[**User Name/Designation of Non-Std Beam]** If Beam Type is "Non-Std", input a name for the Non-Std beam, the indicated beam properties, and the equivalent diaphragm load, if any. Because Non-Std beams can come in any shape the user may input the LLDF or use the button to select the multi-lane LLDF of S/5.5, which is the default (see Figure 11a). If the user inputs a LLDF there will be no adjustments made for number of lanes or the level rule. The LLDF entered (see Figure 11b) will be used to distribute the live load to the beam being rated.



User Name/Designation of Non-Std Beam:	54 (Mod)
Area (in^2):	817
Y_b (in):	26.11
I (in^4):	243178
Beam Depth (in):	54
Top Flange Width (in):	22
Top Flange Thick (in):	4
Live Load Dist. Factor (Calc) (S/5.5): ▾	1.091
Equiv. Diaf Load (k/ft):	

(a)



User Name/Designation of Non-Std Beam:	54 (Mod)
Area (in^2):	817
Y_b (in):	26.11
I (in^4):	243178
Beam Depth (in):	54
Top Flange Width (in):	22
Top Flange Thick (in):	4
Live Load Dist. Factor (Input):	1.350
Equiv. Diaf Load (k/ft):	

(b)

Figure 11. Non-Standard Beam Input.

Steel Stringer

[Overall Span] is the total length, in feet, of the simply-supported steel stringer span (not the total structure length) and is typically the distance from centerline of back bent to centerline of forward bent measured along the centerline of the beam.

[Slab Thickness] is the thickness, in inches, of the slab being supported by the stringers. If the thickness changes from beam to beam, use engineering judgment to choose an appropriate nominal thickness.

[Beam Spacing] is the perpendicular distance between the centerline of the beam being load rated to centerlines of adjacent beams, in feet. This establishes the amount of slab supported by the beam and is also used to calculate the distribution of the live load. If distances to adjacent beams differ, use engineering judgment to determine the value to enter (see Figure 12).

Like prestressed I-beam bridges, the miscellaneous dead load per beam for steel stringer bridges is segregated into two parts, composite and non-composite. **[Misc. Non-Composite Dead Load per Beam]**, in kips per ft., is for permanent load beyond beam 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 (the product of the number of stringers and their lengths). For example, if there are six 60-ft. stringers supporting 3.6 kips of miscellaneous non-composite dead load, the value placed in the field is 3.6kips/(6*60-ft)=0.01 k/ft. Note that the slab weight is not included here because it is calculated by the spreadsheet using the beam spacing and slab thickness entries along with the unit weight of normal weight reinforced concrete (i.e. 150 lbs per cubic ft.).

[Misc. Composite Dead Load per Beam], in kips per ft., is for loads applied after a composite slab is in place. This includes any railing, sidewalks, median, and curbs placed on the composite section. Calculate the input value in the same manner as for the **[Non-Composite Dead Load per**

Beam]. Note that, like slab weight, the overlay load (of user specified thickness) is considered by internal calculations programmed into the spreadsheet.

If the stringer is not composite with the slab, the weight of the railing, sidewalks, median, curbs and diaphragms must be included in **[Misc. Non-Composite Dead Load per Beam]**. This is because an entry in the **[Misc. Composite Dead Load per Beam]** is ignored when the stringer is defined as non-composite, via the **[Composite Action (y/n)]** entry (discussed below).

Cover plates are sometimes attached to stringers to add capacity in high moment regions. This additional steel section is taken into accounted by the **[Top/Bottom Cover Plate Width]** and **[Top/Bottom Cover Plate Thickness]** fields, both input in inches.

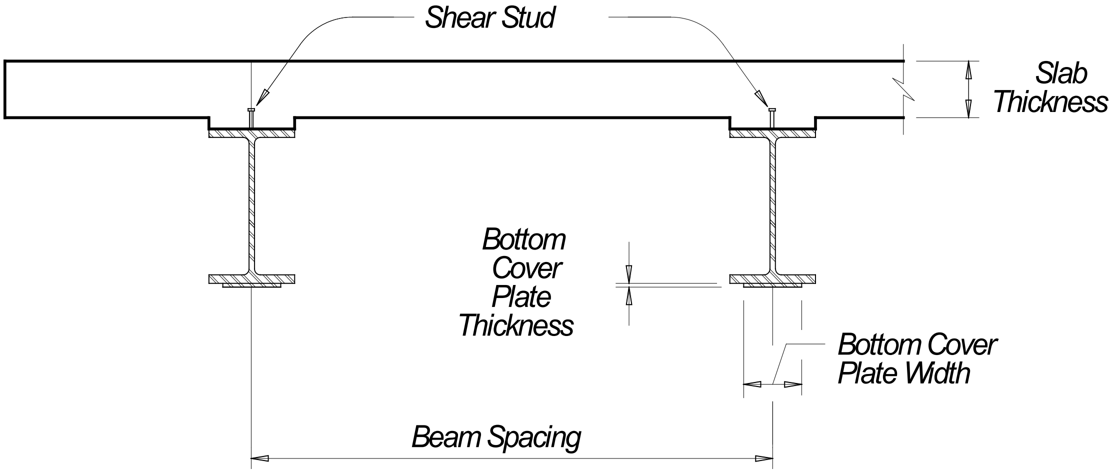


Figure 12. Steel Stringer.

[Span Bearing Length Deduction] is the portion of the overall slab span, in feet, located at each end of the slab, that is between the centerline of the bearing and the centerline of the bent (see Figure 13). The value to be entered for **[Span Bearing Length Deduction]** is the sum of these two described end portions of the slab span, measured along the centerline of the roadway. The spreadsheet subtracts this value from **[Overall Span]** to calculate the effective flexural length of the steel stringer.

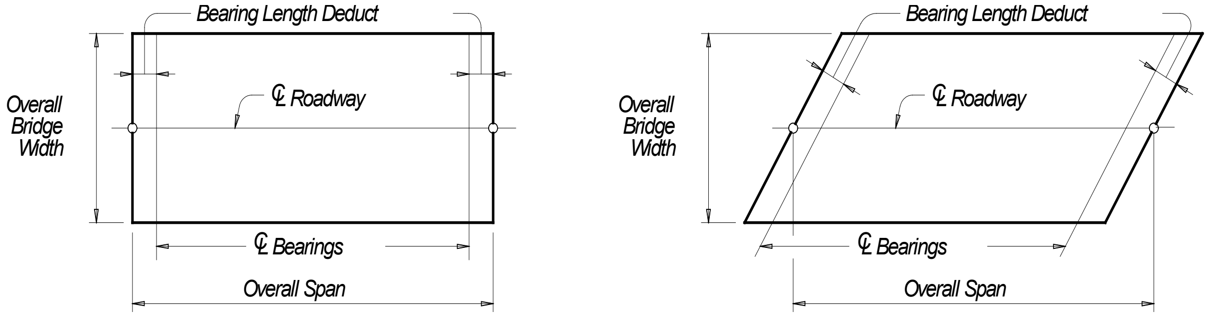


Figure 13. Span Length Deduction.

Some steel bridge structures have been built with the top flange of the stringer embedded in the slab. **[Slab Embedment]**, in inches, of stringer into the slab is measured 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 in the **[Slab Embedment]** field as a negative embedment.

If the plans show shear studs on the top flanges, enter “YES” or “y” under **[Composite Action]**, otherwise enter “NO” or “n”.

A simplifying assumption of the load rating analysis of steel stringers, for the case where no shear studs are provided, is that the top flange is fully braced. This assumption is based on an interpretation of research conducted at the University of Texas at Austin by Yura, et al. Yura, et al. studied buckling of steel stringers supporting wooden decks. They found that considering just the friction between the wooden deck and the steel stringer at the point of application of a wheel load fully braces the stringer against buckling at that point. For the span lengths studied the allowable bending stress considering buckling exceeded the yield stress of the beams. The study further concluded that “[c]oncrete decks are very stiff so the wheel location can be considered a brace point in such bridges” and “[f]riction at the wheel location will force all the girders to buckle simultaneously, so the bridge capacity should not be based on just the most highly stressed single girder.” The steel stringer rating formulations programmed into the spreadsheet assume that buckling will not control (i.e. buckling is not considered). If the span length is much greater than 56-ft (3 brace points—one for each of three HS-20 axles spaced 14-ft apart, first and last of which are 14-ft from supports) or if other than a concrete deck is used, this assumption should be re-evaluated to ensure applicability.

[Rolled Section Depth] and the other information in the *Rolled Section Information* section 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 1852, With Sources as Noted***, compiled and edited by Herbert W. Ferris.

A drop-down list with 1562 entries from the above document is available by clicking on *‘Select Section Designation.’* Scroll down the list until the correct member is found and select it. Then click the “Get Sect Data” button to load the information into the spreadsheet. Please note this drop-down list is applicable only to simple span steel stringer bridges.

Output Fields

Load Ratings

After all information for a structure has been input in the appropriate spreadsheet, the load ratings will be immediately displayed on the spreadsheet. **HS-Rating** is determined assuming the HS-20 truck and lane loading specified by the *AASHTO SS,* Article 3.7. The standard truck with one 8 kip axle and two 32 kip axles (all axles spaced 14 ft. center-to-center) is used as one live load configuration, and the standard lane loading of 0.64 k/ft. with one concentrated load of 18 kips placed at midspan is used as a second live load configuration. Together, these two configurations constitute the HS-20 loading. The maximum moments from the truck and lane loading are enveloped with the midspan maximum value used as the live load moment for load rating purposes. An **H-Rating** is also calculated; the H-20 truck has only two axles (an 8 kip and one 32 kip), thus weighing 32 kips less than the minimum specified by the *AASHTO SS*. The H-20 truck is no longer used as a standard for load rating but there are many bridges designed to H-20, some of which due to their short span length (less than 28 ft) have the same design moment as produced by an HS-20 loading. The spreadsheet also determines the moment due to the Texas Legal Load, but the moment is not used for load rating and not disclosed in the output. This loading was originally used to determine an inspection frequency recommendation that is no longer supported by the spreadsheet suite.

SHV, AASHTO Type 3, Notional Load Rating (NRL), and EV Ratings are also calculated. See figure below for the truck configurations.

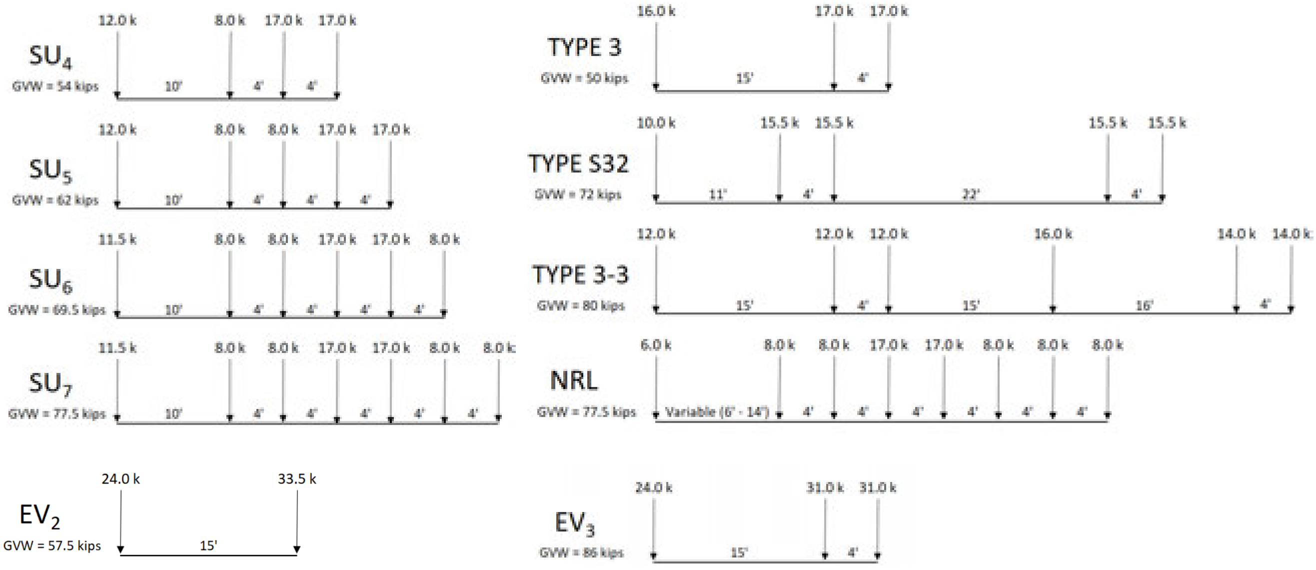


Figure 14. SHV, AASHTO Type 3, NRL and EV Load Configurations

Inventory Rating and Operating Rating. These ratings are defined in the MCEB. See the **General Information** section of that publication for definitions of these terms.

Calculated Values. The *Calculated Values* section of each spreadsheet shows some of the intermediate numbers generated by the program. This section includes **Distribution Factor**, **Impact Factor**, and **Depth of the Concrete Ultimate Stress Block, "a"**. The **Flat Slab** bridge spreadsheet also includes the **Analysis Method**, **Effective Slab Width**, and **Depth of the Concrete Ultimate Stress Block, "a"**, values for the slab and curbs. The calculated distribution of wheel loads to the longitudinal beams is reflected in the **Distribution Factor**. For **T-Beam** and ***Pan Girder*** bridges with a concrete slab, the distribution factor equals S/6, where S = stringer spacing, in feet. For ***Prestressed I-Beam*** and ***Steel Stringer*** bridges, the distribution factor is S/5.5. **Distribution Factor** provisions are found in the *AASHTO SS*, Table 3.23.1. The **Impact Factor** increases the amount of live load on the structure to statically account for dynamic effects. It is based on the length of the span and is limited to a maximum of 30% of the live load moment. The **Depth of the Concrete Ultimate Stress Block, "a"**, is given in inches for all bridges, and is limited to the thickness of the concrete slab except for prestressed concrete beam bridges where it is limited to slab thickness plus top flange depth to the top of web chamfers. The **Live Load Factor (EVx)** is calculated based on the table below found in the NCHRP Project 20-07/Task 410.

Table 3 EV Live Load Factor

EV Frequency	Traffic Volume (One Direction)	Live Load Distribution	EV2	EV3
10 EV crossings per day	ADTT* < 1000 free flowing	Two or more lanes DF**	1.10	1.10
	ADTT > 6000 free flowing		1.40	1.10
	ADTT > 6000 congested		1.50	1.20
1 EV crossings per day	ADTT < 1000 free flowing	Two or more lanes DF**	1.10	1.10
	ADTT > 6000 free flowing		1.20	1.10
	ADTT > 6000 congested		1.30	1.10

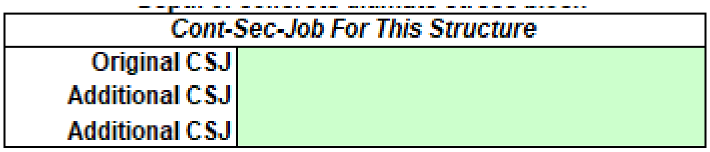
* Annual Daily Truck Traffic; ** = AASHTO STD Specs.

Analysis Method. The **Analysis Method** for ***Flat Slab*** bridges is dependent on whether the bridge has curbs, beams, or neither. If the bridge has curbs or beams on the edge, the procedure outlined in ***Illinois Bulletin No. 346*** is used to distribute moments between the slab and its curbs or beams. If there are no curbs or beams, the ***AASHTO SS,*** Article 3.24.3.2 controls instead. **Effective Slab Width** for a ***Flat Slab*** bridge is the portion of the slab acting integrally with the curb or beam, equaling 4 times the slab thickness. There is no effective slab width when a beam or curb does not exist on a structure. Notice that the **Depth of the Concrete Ultimate Stress Block, "a"** is different for a slab with structural curbs or beams than for a slab with no such structural curb or beam.

The ***Prestressed I-Beam*** bridge rating sheet informs the user as to whether the shape of the composite section is flanged or rectangular and whether the section is over-reinforced or under-reinforced. If the section is over-reinforced, the expected failure mode at maximum moment capacity will be compression in the concrete with tension in steel remaining below the yield stress. Under-reinforced beams will have a more ductile behavior, with the steel yielding before the concrete crushes. The ***AASHTO SS*** specifications allow either case for prestressed concrete members, but only the under-reinforced case for reinforced concrete members.

All dead and live load moments and moment capacities are displayed in the **Moments** section. Descriptions of the applied moments and moment capacities differ, depending on the structure type.

Located at the bottom of each output page, in the right column, is the **Cont-Sec-Job For This Structure** section. When a bridge is widened or lengthened or otherwise rehabilitated, additional CSJ numbers are assigned to the structure and up to two may be entered in this section.



Cont-Sec-Job For This Structure	
Original CSJ	
Additional CSJ	
Additional CSJ	

Figure 15 Con-Sec-Job Input.

The last user input section of each spreadsheet is the *Additional Notes* section, allowing the user to list standards, explain deviations from standards, or show how a calculation was computed, etc.

Theory

Following are all calculations required to determine the moment capacity for each structure type. All **AASHTO** references are according to the *AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002*. All **MCEB** references are according to the *AASHTO Manual for Condition Evaluation of Bridges, 1994, with Interims*.

T-Beam Bridges

Notes

If “a” is less than slab thickness, beams are classified as rectangular (i.e. compression zone is rectangular).

Equations

$$a = \frac{A_s F_y}{0.85 f'_c b}$$

where: a = depth of compression stress block, in inches, see AASHTO 8.16.3.2.

A_s = total area of top and bottom longitudinal steel layers, inches^2

F_y = rebar strength, ksi

f'_c = concrete strength, see Appendix A.

b = effective flange width, see AASHTO 8.10.1.1.

$$d = h - \frac{A_{s_t} d_t + A_{s_b} d_b}{A_{s_{total}}}$$

where: d = distance from extreme compression fiber to centroid of tension reinforcement

(steel centroid to top of slab), in inches
h = slab + beam depth
A_{st} = total area of top layer of longitudinal steel
d_t = distance of top layer of longitudinal steel from bottom
A_{sb} = total area of bottom layer of longitudinal steel
d_b= distance of bottom layer of longitudinal steel from bottom

$$C_u = \phi M_n = \phi\left[\left(A_s F_y\left(d - \frac{a}{2}\right)\right)/12\right]$$

where: C_u = nominal member ultimate capacity used in **MCEB** Eq. 6-1a.
M_n= nominal ultimate moment capacity of T-beam, in kip-feet, see AASHTO 8.16.3.2, Eq. (8-16).
ϕ = strength capacity reduction factor; 0.9 for flexure, see AASHTO 8.16.1.2.2.

Pan Girder Bridges

Notes

For standard Pan Girder bridges, "b" will always equal the beam spacing, as indicated when following the noted provisions of the AASHTO Specifications.

Equations

$$a = \frac{A_s F_y}{0.85 f_c^{'} b}$$

where: a = depth of compression stress block, in inches, see AASHTO 8.16.3.2.
A_s = total area of top and bottom longitudinal steel layers, inches^2
F_y = rebar strength, ksi
f'_c = concrete strength, see Appendix A.
b = effective flange width, see AASHTO 8.10.1.1.

$$d = h - \frac{A_{s_t} d_t + A_{s_b} d_b}{A_{s_{total}}}$$

where: d = distance from extreme compression fiber to centroid of tension reinforcement (steel centroid to top of slab), in inches.
h = slab + beam depth
A_{st} = total area of top layer of longitudinal steel
d_t = distance of top layer of longitudinal steel from bottom
A_{sb} = total area of bottom layer of longitudinal steel
d_b = distance of bottom layer of longitudinal steel from bottom

$$C_u = \phi M_n = \phi\left[\left(A_s F_y\left(d - \frac{a}{2}\right)\right)/12\right]$$

where: C_u = nominal member ultimate capacity used in ***MCEB*** Eq. 6-1a.
M_n = ultimate moment capacity of T-beam, in kip-feet, see AASHTO 8.16.3.2.
ϕ = strength capacity reduction factor; 0.9 for flexure, see AASHTO 8.16.1.2.2.

Flat Slab Bridges

Load rating analysis of a Flat Slab bridge is more complex than T-Beam and Pan Girder bridges. Please refer to the figures and diagrams to better understand these dimensions and variables needed to present explain the analysis.

Ratings are performed separately for the slab, beams, and curbs, but load effects are determined by considering the presence of all elements. The lowest of these three ratings controls the overall structure rating shown in the HS Rating field.

Curb Capacity

$A_{s\text{-slab}}$ is reduced by $\cos^2\phi$ for reinforcement placed normal to supports. In most cases, “a” will be less than “h_{curb}” as shown. $A_{s\text{-slab}}$ considered in curb capacity calculations is only that portion within the adjacent effective slab width.

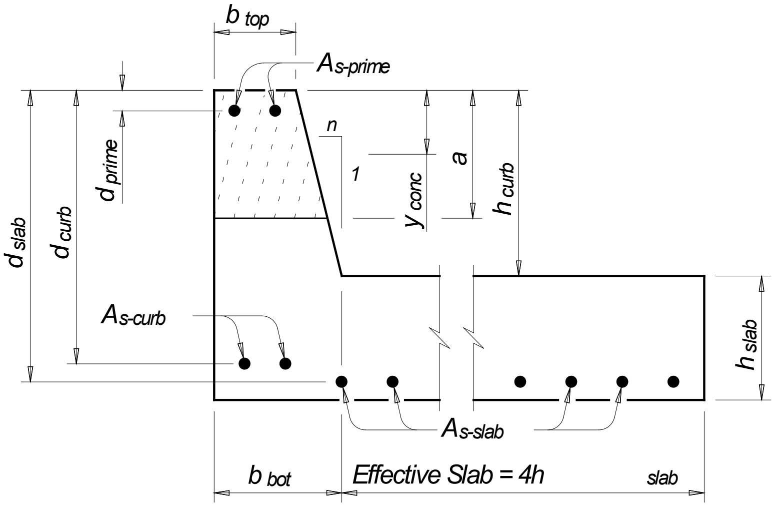


Figure 16. Curb for Flat Slab Bridges.

Compression Steel Component

Make sure that steel is yielded by satisfying AASHTO Eq. (8-24), otherwise ignore the compression steel, making $A_{s\text{-prime}} = 0$ and $\phi M_{n1} = 0$.

If the compression steel is yielded and, $A_{s\text{-prime}} \leq A_{s\text{-curb}}$ then:

$$\phi M_{n1} = \phi A_{s\text{-}prime} F_y (d_{curb} - d_{prime})$$

If the compression steel is yielded and $A_{s\text{-}prime} \geq A_{s\text{-}curb}$ then:

$$\phi M_{n1} = \phi A_{s\text{-}curb} F_y (d_{curb} - d_{prime}) + \phi(A_{s\text{-}prime} - A_{s\text{-}curb}) F_y (d_{slab} - d_{prime})$$

Compressive Stress Block

The depth and centroid of the curbular stress block is derived by setting the compressive force in the curb equal to the available tension force in the net tension steel and solving the resulting quadratic equation for depth, a, resulting in the following formula:

$$a = \sqrt{\left(\frac{b_{top}}{n}\right)^2 + \frac{2\left(A_{s-curb} + A_{s-slab} - A_{s-prime}\right)F_y}{0.85 f_c' n}} - \frac{b_{top}}{n} \qquad \text{where } n = \frac{b_{bot} - b_{top}}{h_{curb}}$$

The centroid at the trapezoidal compressive stress block, measured from the top of curb, is determined as

$$y_{conc} = \frac{3ab_{top} + 2na^2}{6b_{top} + 3na}$$

If a > h_{curb}, a more complex analysis is required. Such an analysis is beyond the scope of this spreadsheet.

Tension Steel Component

If $A_{s\text{-}prime} \leq A_{s\text{-}curb}$, then the following equation applies:

$$\phi M_{n2} = \phi\left(A_{s-curb} - A_{s-prime}\right)F_y\left(d_{curb} - y_{conc}\right) + \phi A_{s-slab} F_y\left(d_{slab} - y_{conc}\right)$$

If $A_{s\text{-}prime} \geq A_{s\text{-}curb}$, then:

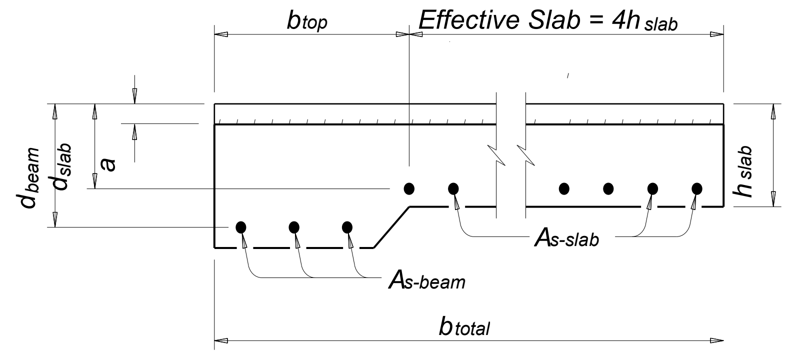
$$\phi M_{n2} = \phi\left(A_{s-slab} + A_{s-curb} - A_{s-prime}\right)F_y\left(d_{slab} - y_{conc}\right)$$

Curb Capacity Equation

$$\phi M_n = \phi M_{n_1} + \phi M_{n_2}$$

Beam Capacity

In most cases, "a" will be less than "d_{slab}". If this is not the case, ignore the contribution of "$A_{s\text{-}slab}$". Always ignore the compression steel in the beam. If reinforcement has been placed **Normal** to supports, $A_{s\text{-}slab}$ is reduced by $\cos^2\phi$. $A_{s\text{-}slab}$ considered in beam capacity calculations is only that portion within the adjacent effective slab width.



The depth of the stress block on the beam is as follows:

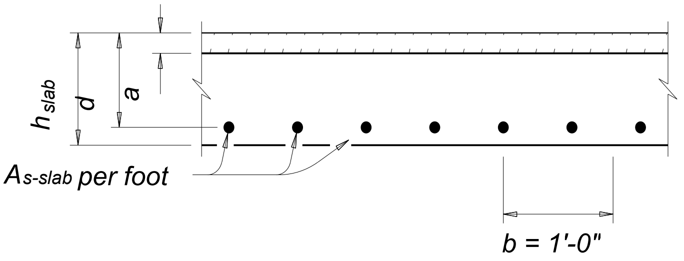
$$a = \frac{\left(A_{s-beam} + A_{s-slab}\right)F_y}{0.85 f_c' b_{total}}$$

The capacity of the beam is:

$$\phi M_n = \phi A_{s-beam} F_y \left(d_{beam} - \frac{a}{2} \right) + \phi A_{s-slab} F_y \left(d_{slab} - \frac{a}{2} \right)$$

Slab Capacity

This is the third capacity on a Flat Slab bridge that must be computed. $A_{s\text{-}slab}$ is reduced by $\cos^2\phi$ for reinforcement placed **Parallel** to roadway.



The depth of the stress block on the slab is as follows:

$$a = \frac{\left(A_{s-slab}\right)F_y}{0.85 f_c' b}$$

The capacity of the slab is:

$$\phi M_n = \phi A_{s-slab} F_y \left(d - \frac{a}{2} \right)$$

Flat Slab Bridge Assumptions

Only slabs designed as FS slabs should consider the contribution of curbs or beams. Other slab bridges were not designed for the curbs to carry load; therefore, it cannot be assumed that they have adequate development length, confinement, sheer capacity, etc., to be considered in the capacity.

If curbs and/or beams are considered in the analysis, then each element of the bridge (left curb, slab, right curb), is assigned an Inventory and Operating rating according to its individual capacity and applied moments.

Inventory rating is based on the least strength element of the bridge (slab, beam, or curb), because this rating is governed by the serviceability required of everyday loads.

Operating rating is a weighted average with curb and slab ratings considered proportionate to their tributary width as compared with the total bridge weight, because this rating is governed by strength required of unusual overloads.

If curbs and/or beams are not considered in the capacity, their moments are distributed according to AASHTO 3.24.3.2 (strip capacity of a one foot strip of slab). If the longitudinal edge beam is not checked, it is assumed that this is equal or stronger than the interior slab.

Transverse steel is assumed adequate for distributing moments and will not control the ratings. This is justified based on experimental research (Illinois bulletin 346) and analytical models which consider cracking.

Skewed slab bridges are rated as equivalent right angle slabs.

Assumptions derived from Illinois Bulletins 369 & 386. See Attachment 2 & 3.

Span length normal to supports is that considered for design moments.

Slab steel area applied to slab capacity is reduced by $\cos^2\phi$ for slab steel running parallel to roadway.

Slab steel area applied to curb capacity (FS slabs only) is reduced by $\cos^2\phi$ for slab steel running normal to supports.

Curb and/or beam dead and live load moments are increased by 10% to account for the additional length above that considered by span length normal to supports.

Prestressed Beam Bridges

Equations

M_u calculations:

$$a = \frac{A_s F_y}{0.85 f'_{c-slab} b}$$

where a = depth of compression stress block, see AASHTO 8.16.3.2, inches
A_s = total area of prestressing strands, inches^2
F_y = strand strength, ksi
$f'_{c\text{-slab}}$ = slab concrete strength, see Appendix A, ksi
b = effective flange width, see AASHTO 8.10.1.1, inches

If "a" is greater than the sum of the slab thickness, haunch at centerline of span, and top flange thickness, the spreadsheet is unable to compute an M_u value. If "a" is less than this sum and "a_{sr}" is greater than zero, M_u equals Mu(flanged). If "a" is less than this sum but "a_{sr}" is equal to or less than zero, Mu = Mu (rectangular).

$$a_{sr} = \frac{A_{sr} f_{su}}{0.85 * f'_{c-slab} * w}$$

where a_{sr} = depth of stress block for rectangular section, inches
A_{sr} = steel area required to develop the compressive strength of the web of a flanged section, inches^2. If "a" is greater than the slab thickness, then $A_{sr} = A_s^* - A_{sf}$. If "a" is less than the slab thickness, then $A_{sr} = 0$.
f_{su} = average stress in prestressing steel at ultimate load, see AASHTO 9.17.4.1, ksi
$f'_{c\text{-slab}}$ = slab concrete strength, see Appendix A, ksi
w = top flange width, inches

$$A_{sf} = \frac{0.85 f'_{c-slab} * (b - w) * t_s}{f_{su}}$$

where A_{sf} = steel area required to develop the compressive strength of the overhanging portions of the flange, inches^2
$f'_{c\text{-slab}}$ = slab concrete strength, see Appendix A, ksi
t_s = slab thickness, inches
b = effective width, inches
w = top flange width, inches
f_{su} = average stress in prestressing steel at ultimate load, see AASHTO 9.17.4.1, Eq. (9-17), ksi

$$f_{su} = f_s' * \left[1 - \left(\frac{\gamma}{\beta_1}\right) * \left(\frac{\frac{A_s^*}{bd} * f_s'}{f'_{c-slab}}\right)\right]$$

where f_{su} = average stress in prestressing steel at ultimate load, see AASHTO 9.17.4.1, Eq. (9-17), ksi
γ = factor for type of prestressing steel, see AASHTO 9.1.2 and 9.17
Low-Relaxation (L.R.) = 0.28
Stress-Relieved (S.R.) = 0.40
A_s^* = total area of prestressing strands, inches^2
β_1 = ratio of depth of equivalent compression zone to depth from fiber of maximum compressive strain to the neutral axis. Value equals 0.85 for concrete strengths, f'_c, up to and including 4,000 psi. For strengths above 4,000 psi, see AASHTO 8.16.2.7
f_s' = ultimate stress of prestressing steel; normally 250 to 270 ksi
b = effective flange width, see AASHTO 8.10.1.1, inches
d = distance from extreme compressive fiber to centroid of the prestressing force, see AASHTO 9.1.2, inches
f'_{c-slab} = slab concrete strength, see Appendix A, ksi

M_u (flanged) calculations:

The Reinforcement Index = $(A_{sr} * f_{su})/(w * d * f'_{c-slab})$, see AASHTO Eq. (9-21)

If Reinforcement Index > $0.36\beta_1$ then it is Over-Reinforced, and

M_u (flanged)= $[(0.36\beta_1 - 0.08\beta_1^2) * f'_{c-slab} * w * d^2 + 0.85 f'_{c-slab} * (b-w) * t_s * (d - 0.5(t_s))]\frac{1}{12}$, see AASHTO Eq. (9-23)

If Reinforcement Index < $0.36\beta_1$ then it is Under-Reinforced, and

$$M_u \text{ (flanged)} = \frac{\left[A_{sr} * f_{su} * \left(d - {}^{a_{sr}}\!/_{2}\right) A_{sf} * f_{su} * \left(d - {}^{t_s}\!/_{2}\right)\right]}{12}$$, see AASHTO Eq. (9-14)

M_u (rectangular) calculations:

The Reinforcement Index = $(A_s^* * f_{su})/(b * d * f'_{c-slab})$, see AASHTO Eq. (9-20)

If Reinforcement Index > $0.36\beta_1$ then it is Over-Reinforced, and

M_u (rectangular) = $\frac{1}{12}\left[\left(0.36\beta_1 - 0.08\beta_1^2\right) * f'_{c-slab} * b * d^2\right]$, see AASHTO Eq. (9-22)

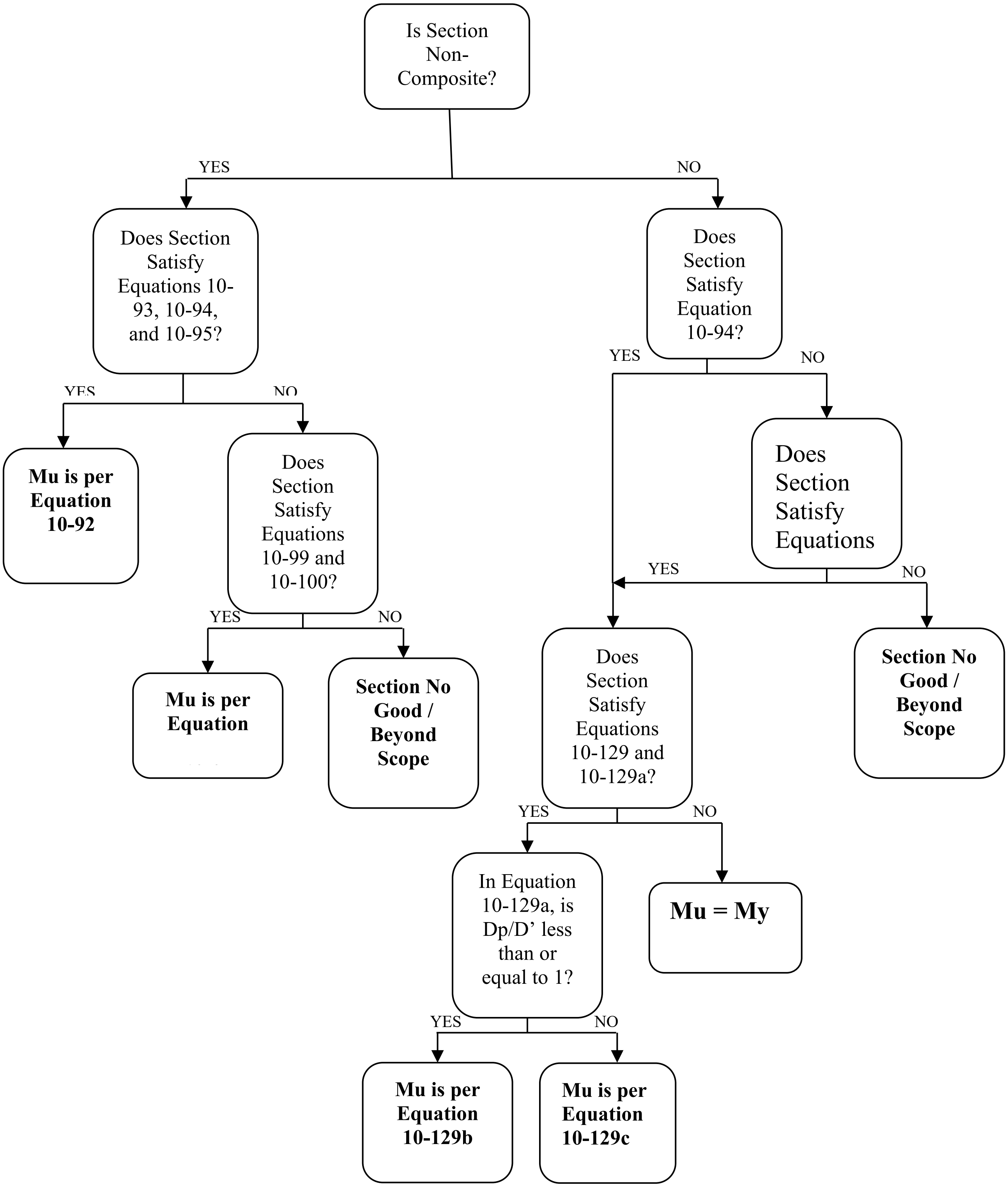
If Reinforcement Index < $0.36\beta_1$ then it is Under-Reinforced, and

M_u (rectangular) = $\frac{1}{12}\left[\left(A_s^* * f_{su}\right)\left(d - {}^{a}\!/_{2}\right)\right]$, see AASHTO Eq. (9-13)

Steel Stringers

Following is a flowchart for determining controlling moment capacities of non-hybrid, simply-supported, unstiffened, fully-braced, steel I-beams and plate girders according to the provisions of AASHTO 10.48 through 10.50.

Per AASHTO 10.48.3, a transition (straight line interpolation) is allowed between Equations 10-92 and 10-98 as long as the web thickness always satisfies Equation 10-94.


Is Section Non-Composite?
YES
NO
Does Section Satisfy Equations 10-93, 10-94, and 10-95?
YES
NO
Mu is per Equation 10-92
Does Section Satisfy Equations 10-99 and 10-100?
YES
NO
Mu is per Equation
Section No Good / Beyond Scope
Does Section Satisfy Equation 10-94?
YES
NO
Does Section Satisfy Equations
YES
NO
Section No Good / Beyond Scope
Does Section Satisfy Equations 10-129 and 10-129a?
YES
NO
In Equation 10-129a, is Dp/D' less than or equal to 1?
Mu = My
YES
NO
Mu is per Equation 10-129b
Mu is per Equation 10-129c

Additional Reference Materials

Lin, T.Y., and Ned H. Burns, *Design of Prestressed Concrete Structures*, 3rd Ed. (City: John Wiley & Sons, Inc., 1981).

Backman, Pat, *FS Slab Bridge Load Rating Theory*, (unpublished Bridge Division paper, Austin: Texas Department of Transportation, date).

Texas Department of Transportation, *Bridge Design Guide*, (Austin: Texas Department of Transportation, 1990).

[1] *Manual for Condition Evaluation of Bridges*, 2nd Edition, American Association of State Highway and Transportation Officials, Washington, D.C., 1994.

[2] Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Texas Department of Transportation, 1993, 1994, and 2004

[3] Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Texas State Department of Highways and Public Transportation, 1982

[4] *Standard Specifications for Highway Bridges,* 17th Edition, American Association of State Highway and Transportation Officials, Washington, D.C., 2002.

[5] Jensen, V.P., and Kludge, R.W., Williams, C.B., "Highway Slab-Bridges with Curbs: Laboratory Tests and Proposed Design Method," Engineering Experiment Station Bulletin Series No. 346, The University of Illinois Urbana, Urbana, IL, July 6, 1943.

[6] Yura, J., Phillips, B., Raju, S., Webb, S. "Bracing of Steel Beams in Bridges," Report No. 1239-4F, Center for Transportation Research, The University of Texas at Austin, Austin, TX, October 1992.

[7] NCHRP Project 20-07/Task 410: Load Rating for the Fast Act Emergency Vehicles EV2 and EV3, HNTB Corp., The City College of New York, New York, NY, March 2019.