MIDAS Training Series

Title: Introduction to Bridge Load Rating

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Bridge Evaluation Training Series

- **Session 1:**
  Introduction to Bridge Load Rating

- **Session 2:**
  Bridge Rehabilitation

Content

- Definition of Load Rating
- Purpose of Bridge Rating
- Difference between Bridge Design and Load Rating
- Application of Load Rating
- Load Rating Levels
- Process of Load Rating
- Load Rating in midas Civil

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What is of Load Rating ?

What is Definition of Load Rating ?

The NBIS (National Bridge Inspections Standards) regulations define load rating as

“The determination of the live load carrying capacity of a bridge using as-built bridge plans and supplemented by information gathered from the latest field inspection.”

Load ratings are expressed as a **rating factor (RF)** or as a **tonnage (for legal and permit vehicles only)** for a particular vehicle. Emphasis in load rating is on the live-load capacity and dictates the approach of determining rating factors instead of the design approach of satisfying limit states.

Purpose of Bridge Rating

Bridge load rating provides a measure of a bridge's ability to carry a given live load in terms of a simple factor, referred to rating factor. These bridge rating factors can be used to aid in decisions about the need for:

(1) Load posting,
(2) Bridge strengthening,
(3) Overweight load allowances, and
(4) Bridge closers

Load Posting	Bridge Strengthening	Bridge Closers

Purpose of the Load Rating

Difference between Bridge Design and Load Rating

Bridge design and rating, though similar in overall approach, differ in important aspect.

Philosophy of Bridge Design

Bridge Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact.

Philosophy of Bridge Load Rating

Bridge ratings generally require the Engineer to consider a wider range of variables than bridge design. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary. The rating procedures presented LRFR recognize a balance between safety and economics.

In most cases, a lower target reliability than design has been chosen for load rating at the strength limit states to rating is done on a more selective basis than is prescribed for design in the AASHTO LRFD Bridge Design Specifications.

Application of Load Rating

New Construction

When designing a new structure, it is required that **RF≥1** for the HL-93 vehicle at the Inventory Level for LRFR load rating design using Part A; therefore, a Legal Load Rating will never be required on a newly designed structure.

Changes in the below category in the existing bridge:

- Live loads
- Dead loads
- Physical condition
- Specifications and Laws

Different Cases for The Load Rating

Load Rating Levels

Midas Civil supports the LRFR Load Rating Design using Part A only. This LRFR methodology consists of three distinct levels of evaluation:

(1) Design load rating

(2) Legal load rating

(3) Permit load rating

The result of each evaluation serve specific purpose and also inform the need for further evaluations. The important factors of each load rating level are summarized as shown in the next slide.

Load Rating Levels

1st Design Load Rating	• Performance of existing bridge • Bridge plan data block
2nd Legal Load Rating	• Single safe load capacity • Bridge posting determination
3rd Permit Load Rating	• Applied to bridges having sufficient capacity • Overweight permit determination

Load Rating Levels

Design Load Rating

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Load Rating Levels

Design load rating is a **first level** assessment of bridges. It is a measure of the performance of existing bridge to current LRFD bridge design standards.

Live Load

At Design load rating level, the HL-93 live-load model of the LRFD is applied, using dimensions and properties of the bridge in its present as inspected condition.

Limit States

Under this check, bridges are screened for the strength limit state at the LRFD design level of reliability. Evaluation at a second lower evaluation level of reliability is also an option. The rating also considers all applicable LRFD serviceability limit states

Purpose

Design load rating can serve as a screening process to identify bridges that should be load rated for legal loads.

Bridges the pass the design load check ($RF \geq 1$) at the Inventory level will have satisfactory load rating for all legal loads that fall within the LRFD exclusion limits.

Load Rating Levels

Level of Design Load Rating

There are two levels of the Design Load Rating:

1) Inventory Rating level

The Inventory rating level generally corresponds to the rating at the design level of reliability for new bridges in the AASHTO LRFD Bridge Design Specifications, but reflects the existing bridge and material conditions with regard to deterioration and loss of section.

2) Operation Rating level

Load rating based of the Operation rating level generally describe the maximum permissible live load to which the structure may be subjected. Generally corresponds to the rating at the Operating level may shorten the life of the bridge.

Legal Load Rating

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Legal Load Rating

This **second level** rating provides a single safe load capacity (for a given truck configuration) applicable to AASHTO and State legal loads.

Live Load

Live load is categorized into the two types according to AASHTO LRFR 2011 as:

1) AASHTO Legal loads, as specified in Article 6A.4.4.2.1a
2) The Notional Rating Load as specified in Article 6A.4.4.2.1b or State legal loads.

Limit States

Strength is the primary limit state for load rating; service limit states are selectively applied.

Purpose

Bridges that do not have sufficient capacity under the design-load rating shall be load rated for legal loads to establish the need for load posting or strengthening.

Permit Load Rating

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Permit Load Rating

This **third level** of rating should only be applied to bridges having sufficient capacity for legal loads. In other words, **Permit load rating should be used only if the bridge has a rating factor greater than 1.0 when evaluated for AASHTO legal loads.**

Live Load

The actual permit vehicle's gross vehicle weight and axle configuration will be the live load used in the permit-load evaluation. The MBE (Manual for Bridge Evaluation) categorizes permit loads into two classes:
1) **Routine/annual permits**, and 2) **Special permits.**

Limit States

Permits are checked using the Strength II limit-state load combination with the Service II limit-state load combination optional for steel bridges to limit potential permanent deformations.

Purpose

Permit load rating checks the safety and serviceability of bridges in the review of permit application for the passage of vehicles above the legally established weight limitations.

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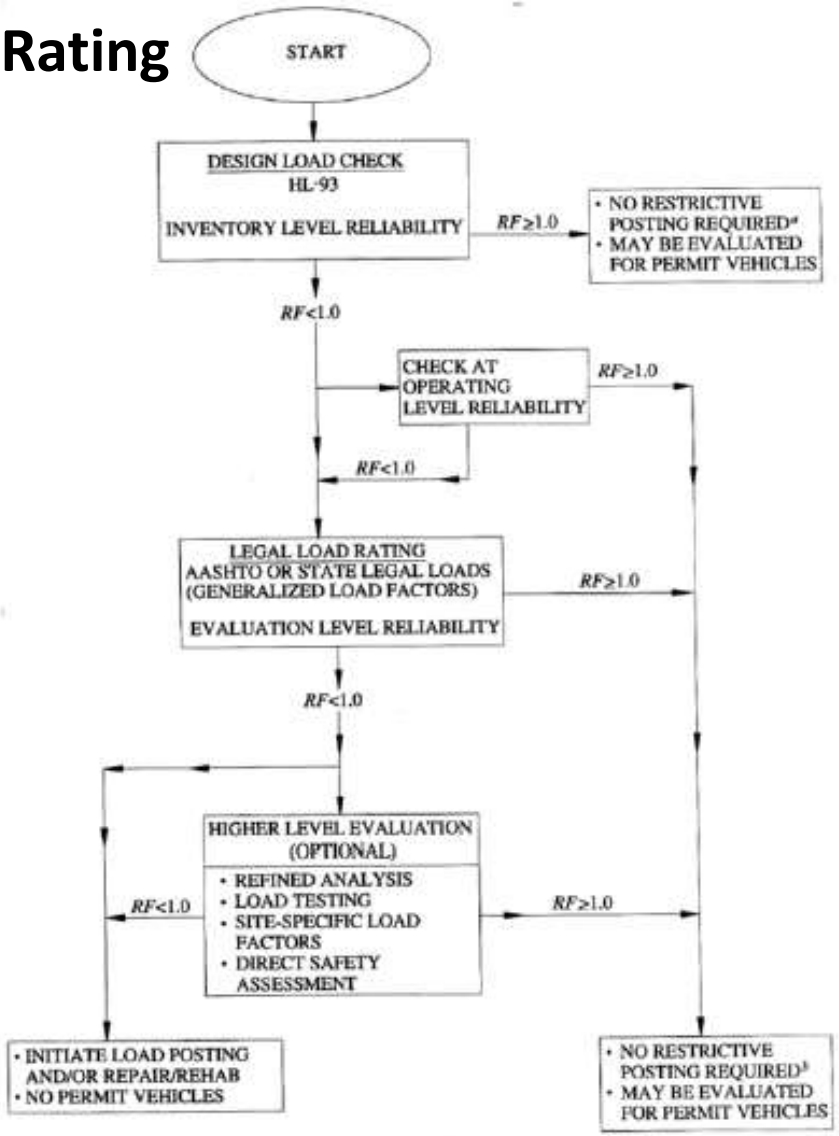
Process of Load Rating

Process of Load Rating



Flow Chart of Load Rating

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Bridge Load Rating Parameters in midas Civil

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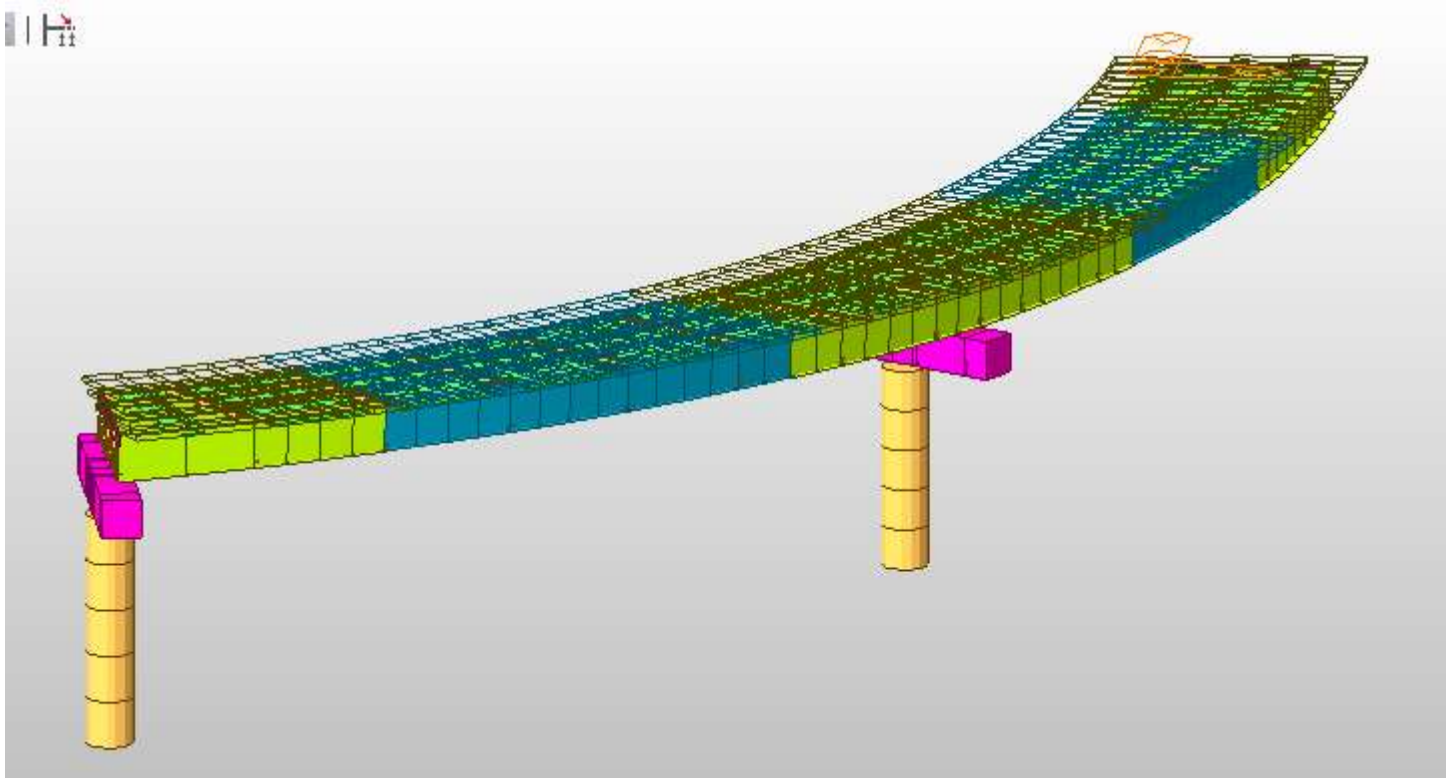
Bridge Load Rating in midas Civil



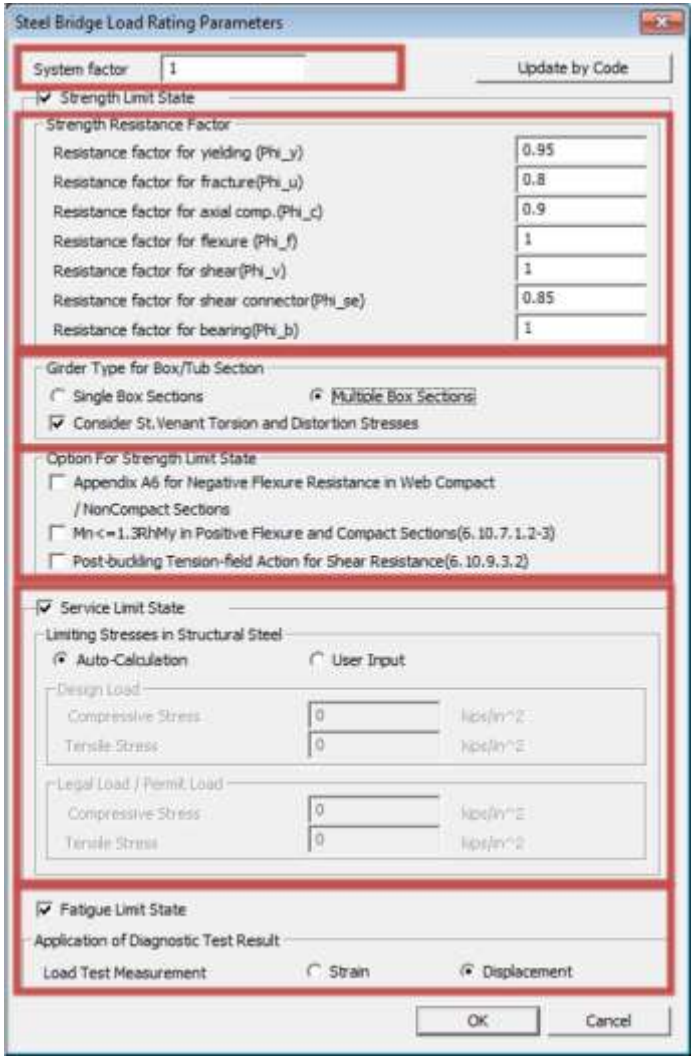
Design Parameters for Steel Composite Load Rating

Rating > Bridge Rating Design > Steel Design> Rating Design Code

The program performs the load rating based on the code selected in this dialog box.

Design Parameters for Steel Composite Load Rating

Rating > Bridge Rating Design > Steel Design> Rating Parameters



(1) The system factor (≤1.2) can be inputted according to the Article 6A.4.2.4, provided in The Manual for Bridge Evaluation, 2nd Edition, 2011. The system factor is multiplied to the flexural strength (Mn) and shear strength (Vn) and, therefore, applied to all elements

(2) Strength Resistance Factor

(3) Girder Type for Box/Tub Section

(4) Options for Strength Limit State

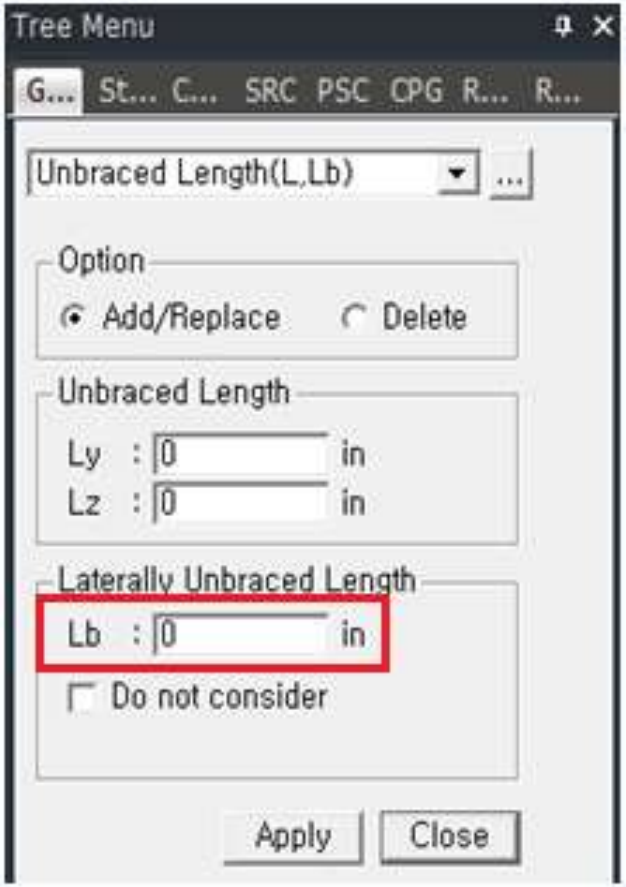
(5) Service Limit State

(6) Fatigue Limit State

(7) Application of Diagnostic Test Result

Design Parameters for Steel Composite Load Rating

Rating > Bridge Rating Design > Steel Design> Unbraced Length

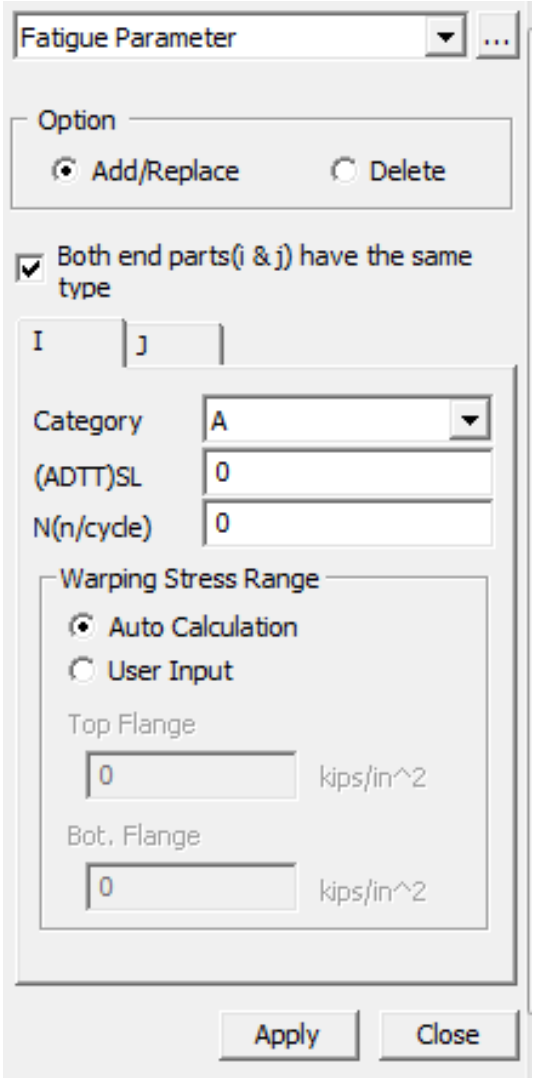


The Unbraced Length for steel composite section can be entered to calculate lateral torsional buckling resistance in compression flange of I Girder or top flange of Tub Girder.

If the lateral unbraced length is not inputted, the program will use span lengths entered in Span Information. If Span Information was defined either, the lateral unbraced length is applied as the corresponding element length.

Design Parameters for Steel Composite Load Rating

Rating > Bridge Rating Design > Steel Design> Fatigue Parameter



Category: Category defined by 75yr-(ADTT)SL equivalent to infinite life (Table 6.6.1.2.3-2).

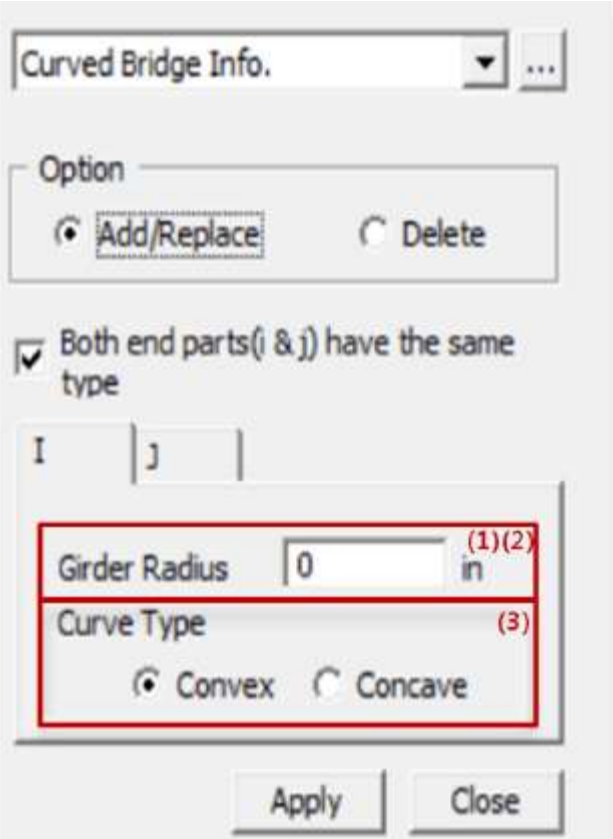
(ADTT)SL: Number of trucks per day in a single-lane averaged over the design life (3.6.1.4.2) Value can be manually calculated as per 3.6.1.4.2-1.

N: Number of cycles per truck passage.

Warping Stress Range: For the verification of fatigue, flexure stress is calculated as the summation of Longitudinal Bending Stress Range and Longitudinal Warping Stress Range.

Design Parameters for Steel Composite Load Rating

Rating > Bridge Rating Design > Steel Design> Curved Bridge Info



Once the girder radius value of the element units in the steel composite section is entered, the corresponding elements are categorized as curved bridges.

(1) Radius is used for the review of shear connector's pitch and the moment of inertia of area for the longitudinal stiffener attached to web.

(2) Curve Type - Convex, Concave

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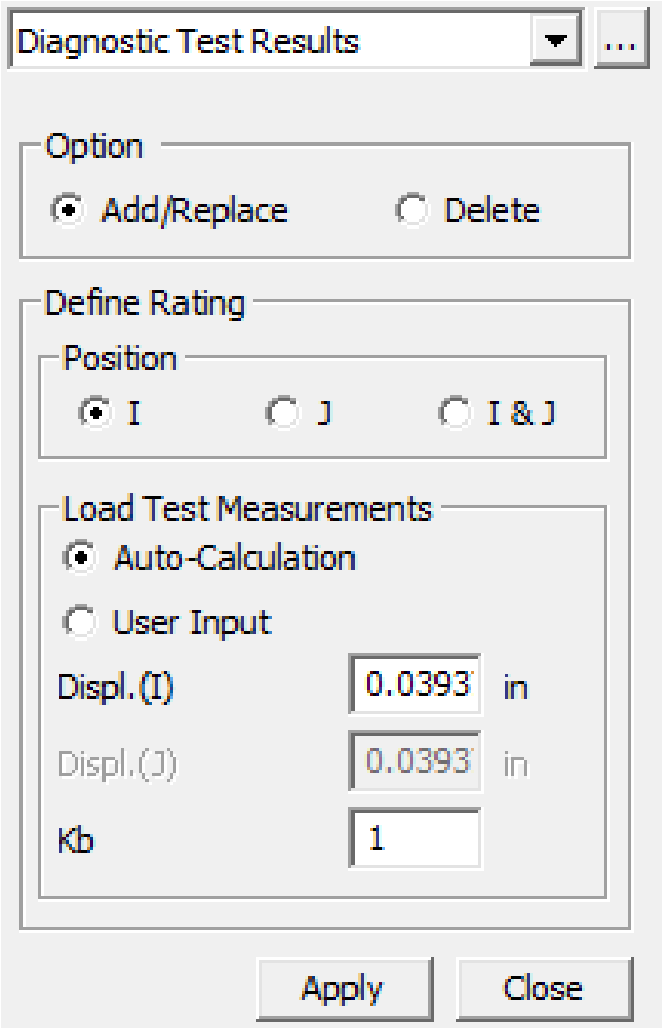
Design Parameters for Steel Composite Load Rating

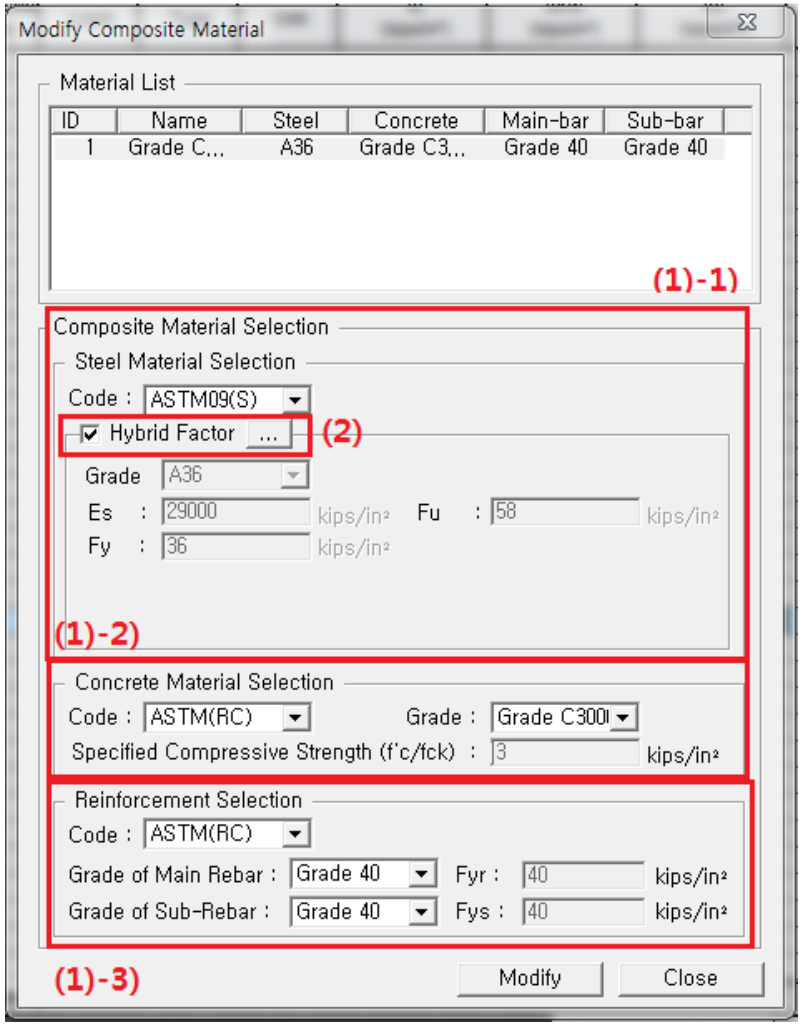
Rating > Bridge Rating Design > Steel Design> Diagnostic Test Result...



Adjustment factor resulting from the comparison of measured test behavior with the analytical model can be considered to calculate the load-rating factor based on the test result.

Design Material Data

Rating > Bridge Rating Design > Steel Design> Rating Material



In this dialog box, the Material Properties can be modified for the calculation of the structure capacity.
The material utilized for composite sections are provided in the SRC material properties. The material should be defined as SRC Type.

1) Steel of the Steel Girder Section

Hybrid Factor

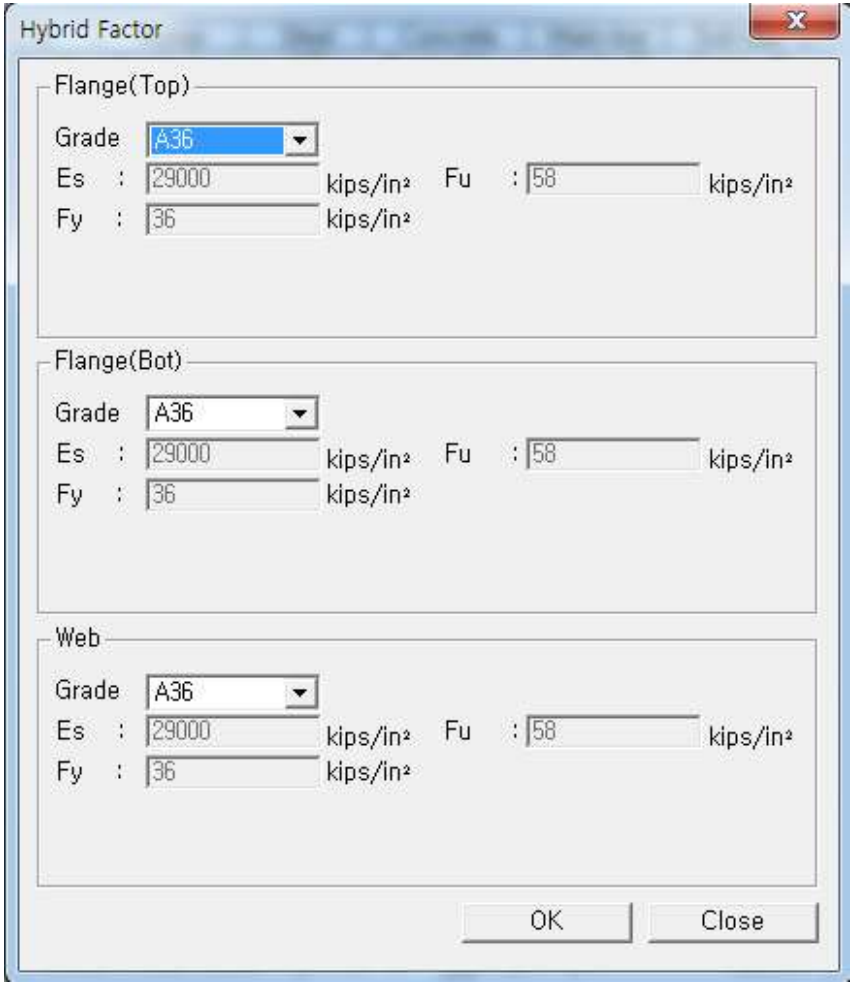
Hybrid Factor is considered in the case where flanges and web have different material properties.

2) Concrete of the Concrete slab

3) Steel Rebar of the Concrete slab

Design Material Data

Rating > Bridge Rating Design > Steel Design> Rating Material



(2) **Hybrid Factor(Rh)**

When the check box for Hybrid Factor is selected, icon on the right is activated. The different materials for the top and bottom flanges and web of the steel girder can be defined.

Hybrid Factor (Rh) is determined based on these material information.

Settings for Load Rating

Rating > Bridge Rating Design > Steel Design> Rating Group Setting...

The Bridge Rating Group Setting Dialog allows users to apply Condition Factors per different groups defined already and i- and j-end check positions.

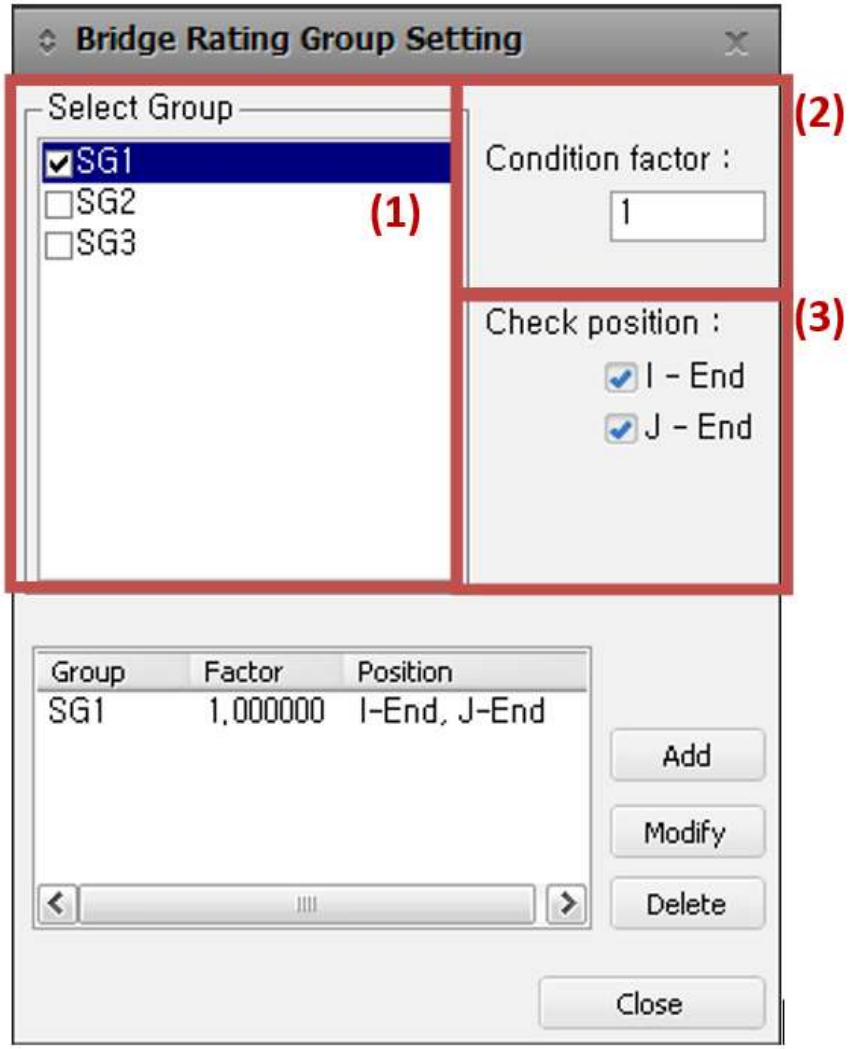
(1) Selected Groups are targeted for the design of the Rating Factor. Structural groups composed of SRC material properties are shown in the list after performing an analysis.

(2) Different values of Condition Factor, $\boldsymbol{\varphi c}$, can be applied to different Structure Groups of elements. In the program, the Condition Factor is internally multiplied to Nominal Flexural Strength/Resistance, Nominal Shear Strength and Nominal Fatigue Resistance to calculate the Load Factor. Condition Factor can be inputted in accordance with the Article 6A.4.2.3 of The Manual For Bridge Evaluation, 2nd Edition, 2011.

(3) The Check Position, i- and/or j- end, is considered and selected for the Groups selected for the design.

Settings for Load Rating

Rating > Bridge Rating Design > Steel Design> Rating Group Setting...



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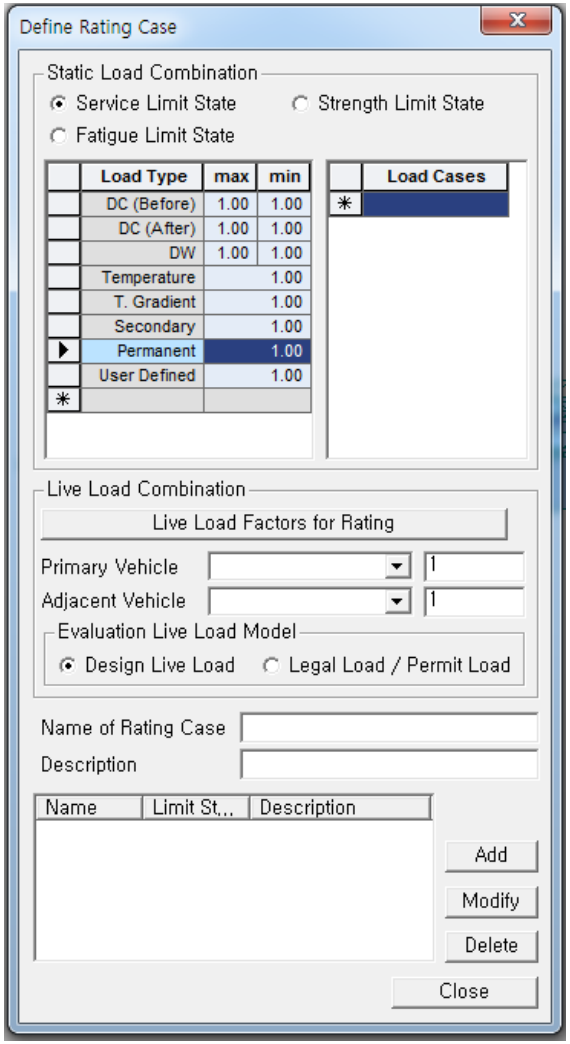
Settings for Load Rating

Rating > Bridge Rating Design > Steel Design> Define Rating Case...



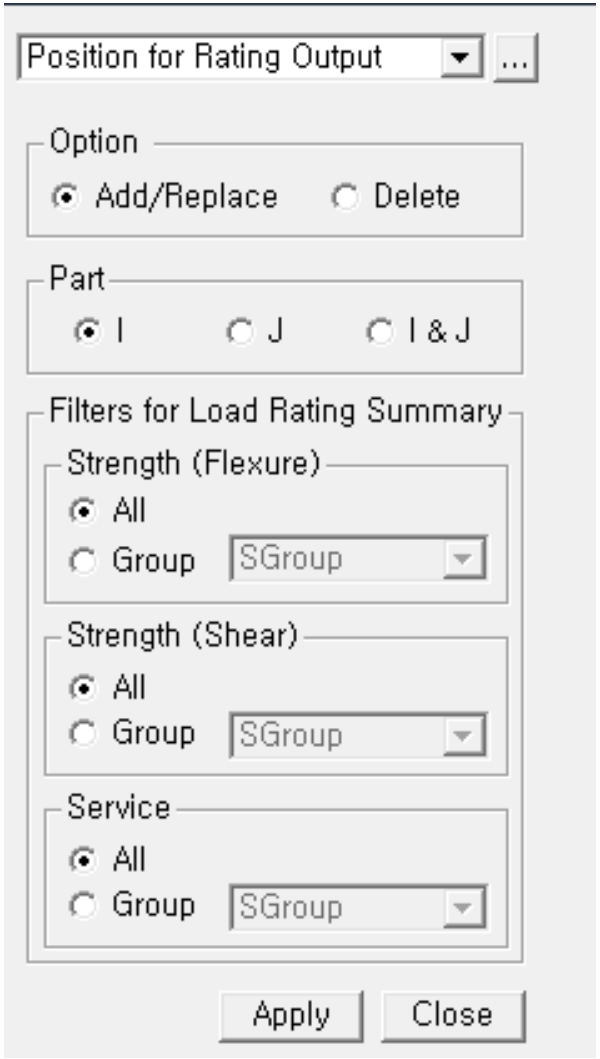
In Define Rating Case Dialog, Load Factor is defined for each of the Service Limit State, Strength Limit State and Fatigue Limit State.

(1) For the Fatigue Limit State calculation, only live load can be selected.

(2) Maximum and minimum Load Factors for each Load Type (DC, DW, ...) can be manually modified by users as per Table 6A.4.2.2-1 of The Manual for Bridge Load Evaluation, 2nd Edition, 2011 and Table 3.4.1-2 of AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012.

Settings for Load Rating

Rating > Bridge Rating Design > Steel Design> Position for Rating Output...



In this Dialog, the Position for Rating Output is inputted.

(1) Define the Position for Rating Output.

(2) Users can select Groups in the Filters for Load Rating Result Table of Excel Report. Select All in order to find the most critical elements from all composite sections. Select Group to limit the target elements to find out the most critical elements.

(3) When Apply is clicked in this dialog box, the elements to be printed in the output is defined and saved.

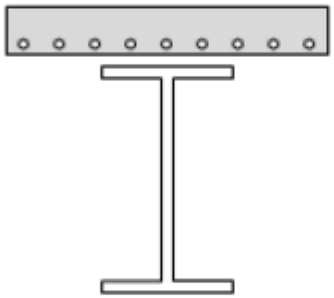
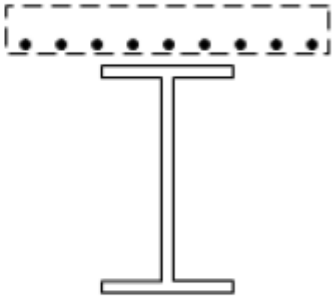
Composite Section Data

Rating > Bridge Rating Design > Steel Design> Longitudinal Reinforcement

Longitudinal Reinforcement

In a steel composite section, the longitudinal reinforcements are arranged within the concrete deck. The strength is calculated as shown in the below table.

[Table3.5] Material Application for Strength Calculation

Case	Positive Flexure	Negative Flexure
Figure		
Concrete Slab	Apply	None
Reinforce-ment	None	Applied

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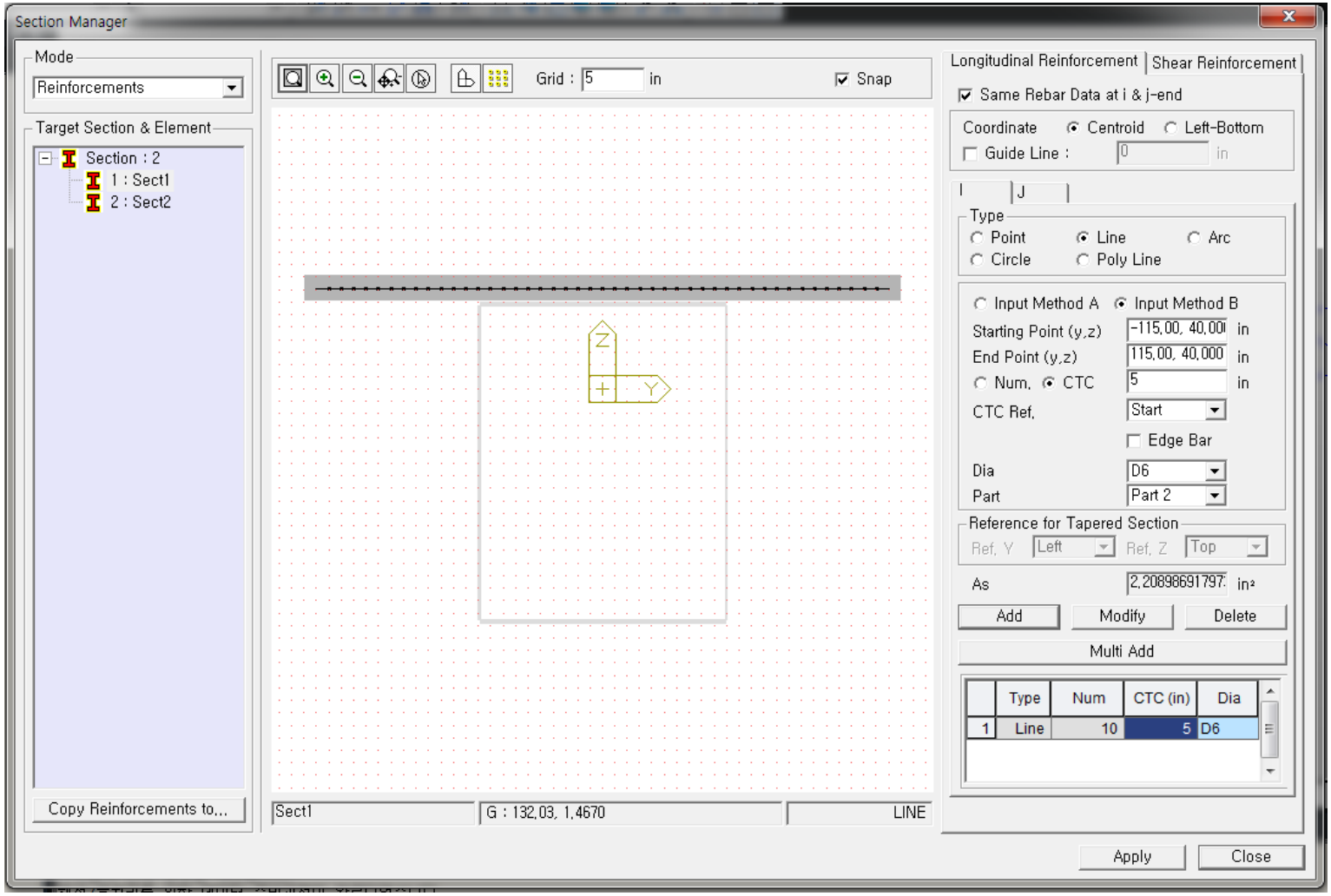
Composite Section Data



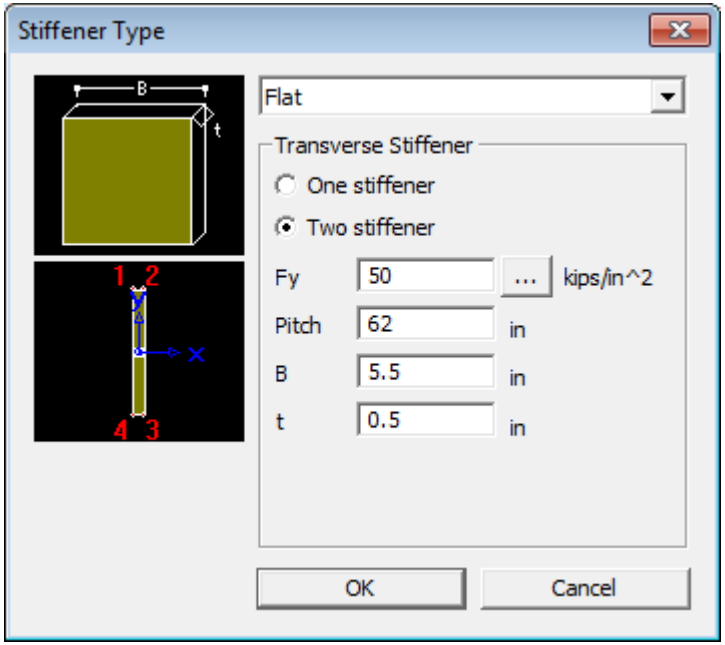
Longitudinal Reinforcement Dialog

Composite Section Data

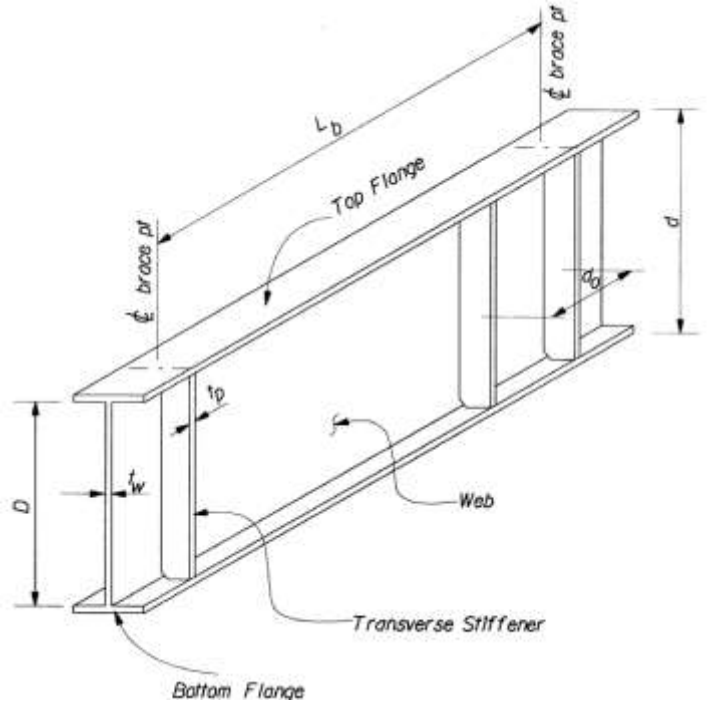
Rating > Bridge Rating Design > Steel Design> Transverse Stiffener…

Transverse Stiffener

When the transverse stiffeners are installed, the existence and spacing between stiffeners determine whether the web is stiffened or unstiffened under strength limit state.



Stiffener Type Dialog



Transverse Stiffener Parameters

Composite Section Data

Rating > Bridge Rating Design > Steel Design> Transverse Stiffener…

Transverse Stiffener
(1) Stiffener Type

1) One / Two Stiffener Option Button
Choose between one or two stiffeners. The two stiffener option is available for I/Box/Tub sections.

2) Pitch (do)
Pitch refers to the Transverse Stiffener spacing. At the strength limit state, this can be used to distinguish between stiffened and unstiffened webs or calculate shear strength of the web.

Application of Bridge Load Rating

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Application of Bridge Load Rating

Rating Factor

The Bridge Load Rating function of midas Civil calculates the Rating Factor (RF) at i/j nodes of elements for the Rating Cases according to AASHTO LRFR 2011 standard and finds the minimum RF.

Rating load carrying capacity needs to be done at three different levels - Design Load Rating, Legal Load Rating, and Permit Load Rating - according to the AASHTO LRFR 2011. Midas Civil Bridge Load Rating calculates RF for Design Load Rating and Legal Load Rating for the load cases defined in Define Load Case.

The RF calculated in Midas Civil determines whether it is safe to carry the Primary Vehicle. If RF>1 it is safe and the larger RF, the greater the load carrying capacity of the bridge.

Application of Bridge Load Rating

RF Calculation as per AASHTO LRFR

The RF value shall be taken as below according to the LRFR standard:

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$

Where,

RF : Rating factor

C : Capacity

f_R *: Allowable Stress specified in the LRFD code*

DC : Dead-load effect due to structural components and attachments

DW : Dead-load effect due to wearing surfaces and utilities

P : Permanent loads other than dead loads

LL : Live load effect

IM : Dynamic load allowance

γ_{DC} *: LRFD load factor for structural components and attachments*

γ_{DW} *: LRFD load factor for wearing surfaces and utilities*

γ_P *: LRFD load factor for permanent loads other than dead loads*

γ_{LL} *: Evaluation live load factor*

φ_c *: Condition factor*

φ_s *: System factor*

φ *: LRFD resistance factor*

Rn : Nominal member resistance

Case	C
Strength Limit States	$C = \varphi_c \varphi_s \varphi R_n \quad (\varphi_c \varphi_s \geq 0.85)$
Service Limit States	$C = f_R$

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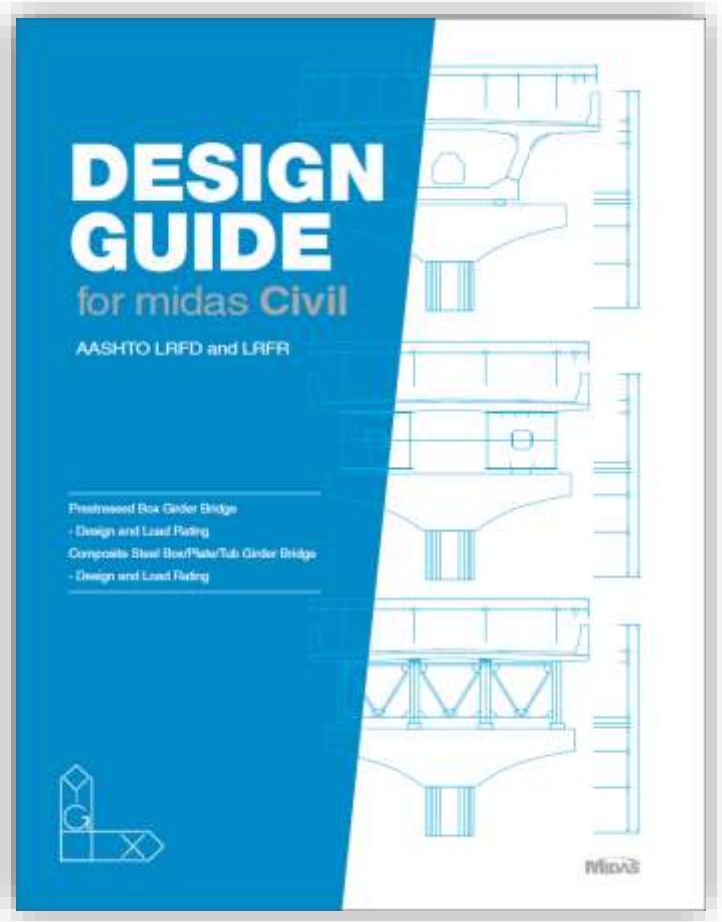
Design Guide

User Design Guide for midas Civil AAShTO LRFD and LRFR



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http://globalsupport.midasuser.com/

Thank you