

NSBA Heat Curve Calculator - Overview

Version 2.01 - Final

Heat Curving

Heat curving is a process in which a straight girder is heated to induce horizontal curvature (Figure 1). A combination of strip heating and V-heating may be utilized to achieve the proper curvature (Figure 2). Heat curving is a well-established method, and it does not adversely affect the material properties of the girder. Providing this option can make a steel bridge more economical to fabricate. However, not permitting the use of heat curving should not eliminate the use of horizontally curved girders entirely, as the girders can be fabricated using cut-curving techniques for the flanges instead.



Figure 1: Heat Curving Result.



Figure 2: Heat Curving Process.

AASHTO Requirements

The AASHTO LRFD Bridge Design Specifications allow the use of heat curving, with restrictions. For horizontally curved steel rolled beam and constant depth welded I-section plate girders, the AASHTO LRFD Bridge Design Specification Article 6.7.7.2 requires that Engineers indicate on the contract documents whether heat curving is permitted in accordance with the Article 14.3.2.2 of the LRFD Steel Bridge Fabrication Specification, 1st Edition. However, evaluation and interpretation of this article can be challenging for even the most seasoned engineers.

Heat Curve Calculator Overview and Operation

The NSBA Heat Curve Calculator is a free Excel based tool intended to assist Engineers in evaluating whether horizontally curved bridge girders can be fabricated using heat curving. The spreadsheet implements Article 14.3.2.2 of the LRFD Steel Bridge Fabrication Specification, 1st Edition. Flowcharts have also been provided in this spreadsheet. Each flowchart provides a procedural outline of Articles 14.3.2.2.2, 14.3.2.2.3, 14.3.2.2.4 and 14.3.2.2.5 (Figure 4). Each of the worksheets within this spreadsheet have been protected to prevent unintended changes to cells containing formulas, graphics, and text. While not advised, individual sheet protection can be disabled by toggling the “Unprotect Sheet” icon located in the “Review” group of the Excel ribbon bar. A color scheme has also been used to indicate status or intended use of different cells. For example, user input is intended only in cells filled with the color "orange". See Figure 3 for more information.

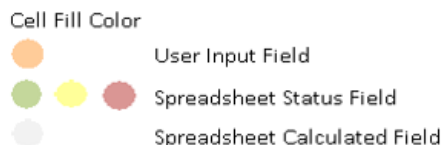


Figure 3: Cell Color Key.

Collectively, the information entered on the “Input” worksheet represents the data for an individual field section. The “Heat Curve Status” shown is the result based on the controlling section entered. The user must enter each unique prismatic section (i.e., each unique combination of flange, web, and yield strength along the field section) within each girder field section. Although entry for only six sections is provided, there may be additional sections beyond that which need to be evaluated. This can be accomplished by overwriting an existing section input or creating a duplicate spreadsheet for those additional sections. In those cases, the user would be responsible for keeping track of the status for each section entered and aggregating the results.

The “Input” worksheet has been divided into five regions (Figure 5). The following describes each region:

- **Girder Properties – Input:** The user should first enter the “Centerline Radius” for the girder that is being checked. Next, enter the web and flange plate dimensions along with their material grade for each prismatic section within the field section under consideration. Although space has been provided for six sections, the user need only enter enough information to capture each of the unique prismatic sections within the field section. All other section information should be left blank. The “Heat Curve Status” is an overall status that indicates whether the field section being evaluated can or cannot be heat curved based on the controlling section entered. It will display either “CANNOT BE HEAT CURVED” or “CAN BE HEAT CURVED”. If all sections entered can be heat curved but their calculated minimum radius for heat curving is greater than the centerline radius entered, the overall status will be “CANNOT BE HEAT CURVED”. If any one section entered cannot be heat curved, the overall status will be “CANNOT BE HEAT CURVED”
- **Minimum Radius Summary:** For each section that is entered, a minimum radius for heat curving is calculated according to Article 14.3.2.2. The result can be either a numeric value, which is the minimum radius for heat curving for that the field section, or “NG”. A value of “NG” indicates that the section cannot be heat curved. This means the entire field section cannot be heat curved. Cells with a value of “NG” will also be filled with a “red” color (Figure 3).
- **Cross-Sectional Criteria:** Each prismatic section is first checked against Article 14.3.2.2.2. Depending upon the cross-section geometry, the provisions of this article will be checked to determine whether the section can be heat curved. If it can be heat curved, a minimum radius is defined based upon the flange geometry. The minimum radius based upon the flange geometry will be either 150 ft or 1000 ft. A minimum radius will also be calculated according to the provisions of Article 14.3.2.2.3, 14.3.2.2.4 and/or 14.3.2.2.5, as applicable. The minimum radius based upon the flange geometry will then be compared against those values to determine which controls. Note that the results of Article 14.3.2.2.2 are echoed in “Minimum Radius Calculation” to make visual checking of the spreadsheet easier.
- **Hybrid Girder Criteria:** If a section is hybrid, Article 14.3.2.2.5 must be evaluated. The Hybrid Girder Criteria portion of the spreadsheet performs those checks. Articles 14.3.2.2.3 or 14.3.2.2.4 may also need to be checked. These articles are checked, and the final minimum radius is reported

under “Minimum Radius Calculation”. Any value that is shown as “DNA” implies that the equation or check does not apply to the section being checked.

- Minimum Radius Calculation:** The minimum radii for heat curving determined according to the provisions of Articles 14.3.2.2.3, 14.3.2.2.4 and 14.3.2.2.5 are evaluated in this section. The $R_{calculated}$ for each article is compared and the largest value is shown in “Minimum Radius Summary” for each section.

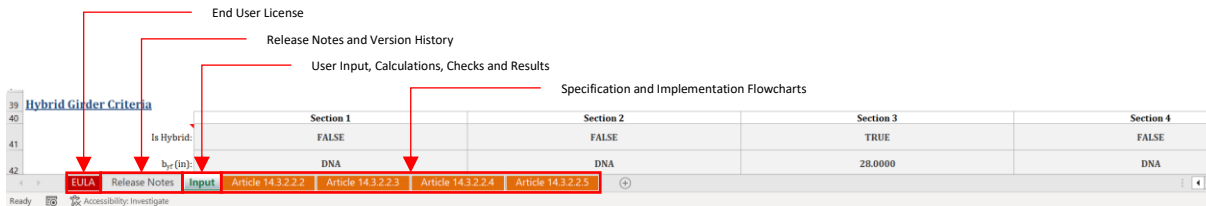


Figure 4: Spreadsheet Worksheets.

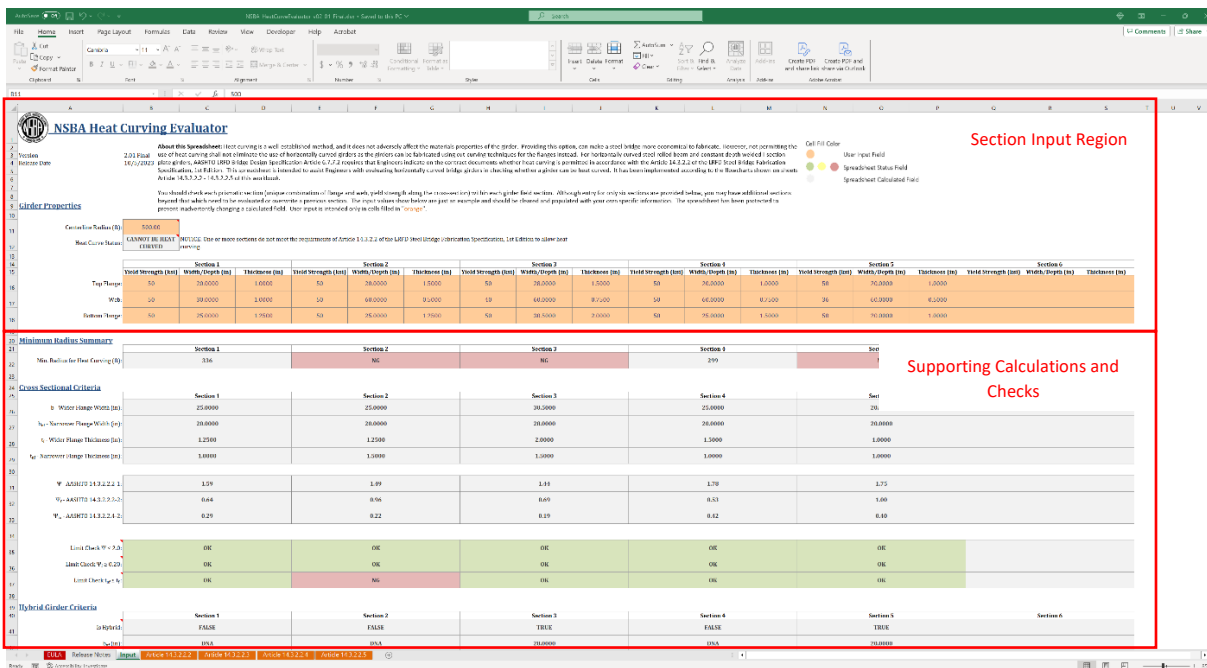


Figure 5: Spreadsheet Input, Calculation and Results Sheet Overview.

Article 14.3.2.2 of the LRFD Steel Bridge Fabrication Specification, 1st Edition can be challenging to interpret for even the most experienced designer. Flowcharts were developed to describe the process of evaluating an individual prismatic section and document the calculations performed in this spreadsheet. The flowchart is executed once, from start to end, for every unique prismatic section within a field section. Off page reference symbols are used to interconnect flowcharts. For example, consider the flowchart shown in Figure 6. If the section being evaluated is hybrid and all cross-section criteria are met, Article 14.3.2.2.5 is to then be evaluated. The corresponding flowchart for this article is located on the sheet labeled “Article 14.3.2.2.5”. No equations are provided in the flowcharts, so the user will need to have the LRFD Steel Bridge Fabrication Specification available to perform any verification calculations.

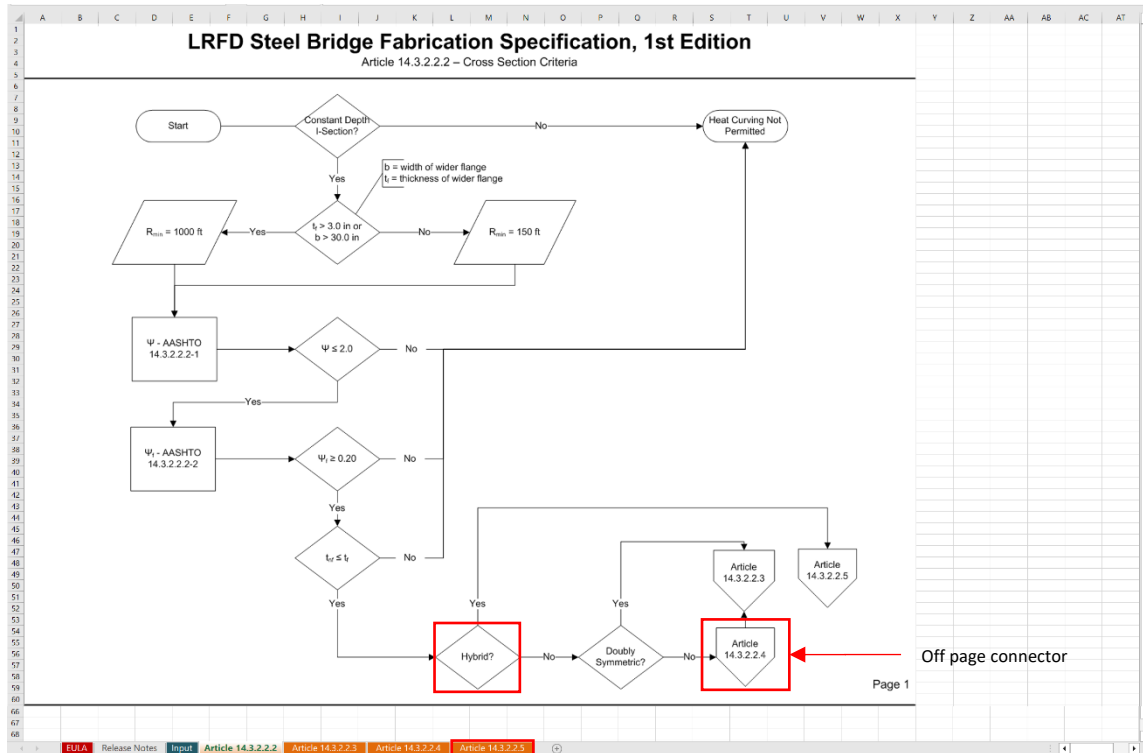


Figure 6: Example Specification Flowchart.

About this Version

This version of the NSBA Heat Curve Calculator has been implemented according to the LRFD Steel Bridge Fabrication Specification, 1st Edition. If any issues are found with this spreadsheet, please contact the NSBA at nsbaresources@aisc.org.