

AASHTOWare BrDR 7.5.0

Steel Design Tool

Getting Started

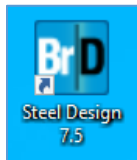
Introduction

The Steel Design Tool provides the overall framework including libraries of vehicles, appurtenances, and materials as well as the capabilities required to analyze and design steel plate girders in accordance with the AASHTO LRFD specification, considering requirements for constructability, service, strength, and fatigue.

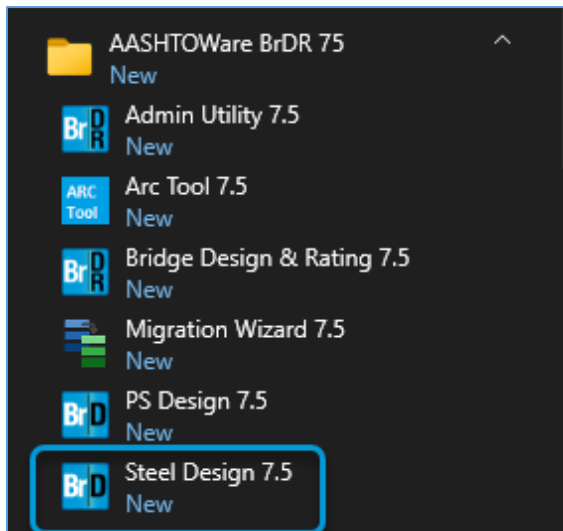
The user can describe the overall bridge framing plan as a girder system that includes multiple steel plate girders. The girder system definition is limited to regular geometries with constant and equal beam spacing and the same skew at all supports. The tool can compute constant live load distribution factors and determine both dead loads and live loads for each beam based on the input provided for the girder system structure definition.

Launch Steel Design Tool

The Steel Design Tool is installed with the BrDR installation. After the BrDR installation is completed successfully, the Steel Design Tool is initiated by double-clicking the Steel Design Tool shortcut icon from the desktop,



or select Windows Start menu on the taskbar ► AASHTOWare BrDR 75 ► Steel Design 7.5.



STL14 - Steel Design Tool – Getting Started

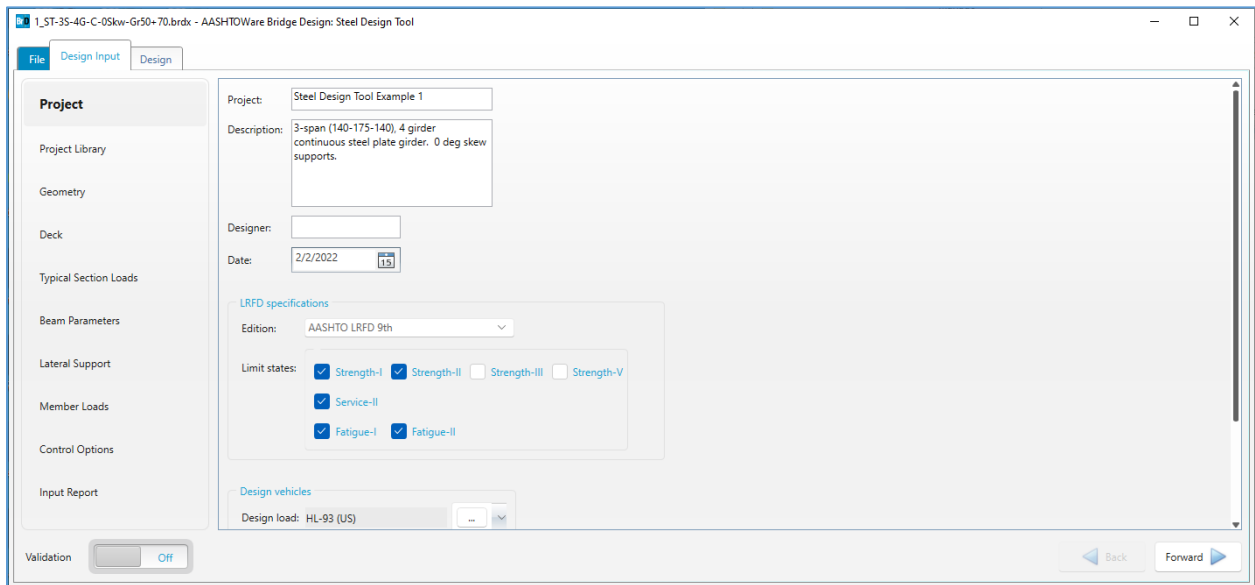
Four design project examples are provided with the installation. The design project examples (.brdx) are included in the same folder where the Steel Design Tool is installed. The default installation folder is *C:\Program Files\AASHTOWare\BrDR75\SteelDesign*. The following table describes the four design project examples.

Design Project Examples				
File name	1_ST-3S-4G-C-0Skw-Gr50+70.brdx	2_ST-5S-4G-C-0Skw-Gr50+70.brdx	3_ST-3S-5G-C-46Skw-Gr50.brdx	4_ST-1S-6G-C-35Skw-Gr50-Sdwlk.brdx
General Description				
Number of spans	3	5	3	1
Span lengths (ft)	140 – 175 – 140	190 – 240 – 240 – 240 – 190	88 – 148 – 88	66
Number of girders	4	4	5	6
Girder spacing (ft)	12	12	7.67	6.58
Deck overhang (ft)	3.5	4.8675	2.3542	1.7604
Web depth (in)	69	96	44	20
Support skew angle	0	0	-46	-35
Composite	Yes	Yes	Yes	Yes
Deck thickness (in)	9.5	9.5	8	8
Steel grade – Web	50ksi	50ksi	50ksi	50ksi
Steel grade – Flange	70ksi	70ksi	50ksi	50ksi
Loading				
Live load	HL-93	HL-93	HL-93	HL-93
Permit vehicle	Yes	Yes	Yes	Yes
Fatigue vehicle	Yes	Yes	Yes	Yes
Pedestrian load	No	No	No	Yes

Quick Tour

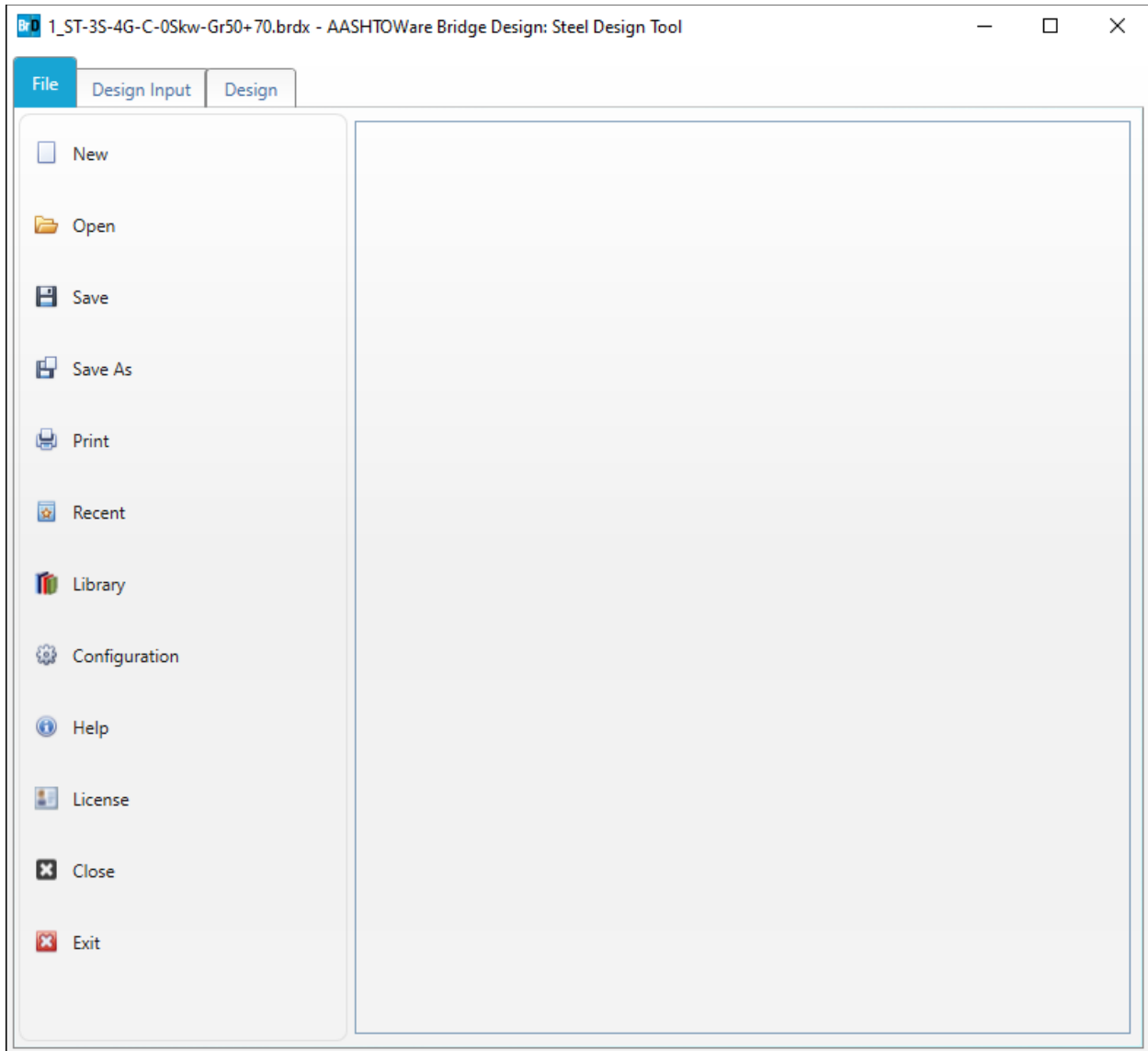
Launch Steel Design Tool and select Open on the File tab. Open the *1_ST-3S-4G-C-0Skw-Gr50+70.brdx* file provided with the installation.

The Steel Design Tool user interface is composed of the **File**, **Design Input** and **Design** tabs.

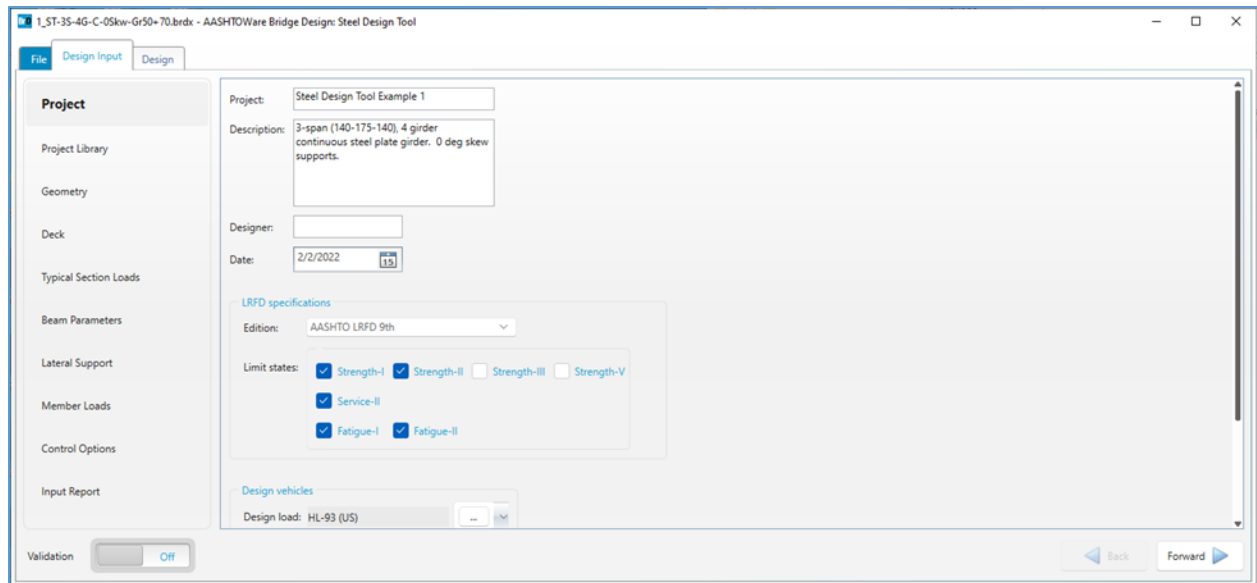


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The **File tab** is used to create new design projects, open existing design projects, and save the current design project. **Print** sends the design project to the printer. **Recent** shows a list the recently opened design projects for easy access. **Library** manages the appurtenances, materials, and vehicles for use in the design projects. **Configuration** allows modification to the configuration of new design project. **Help** provides access to the Steel Design Tool Help and technical support information.



Select the **Design Input** tab.



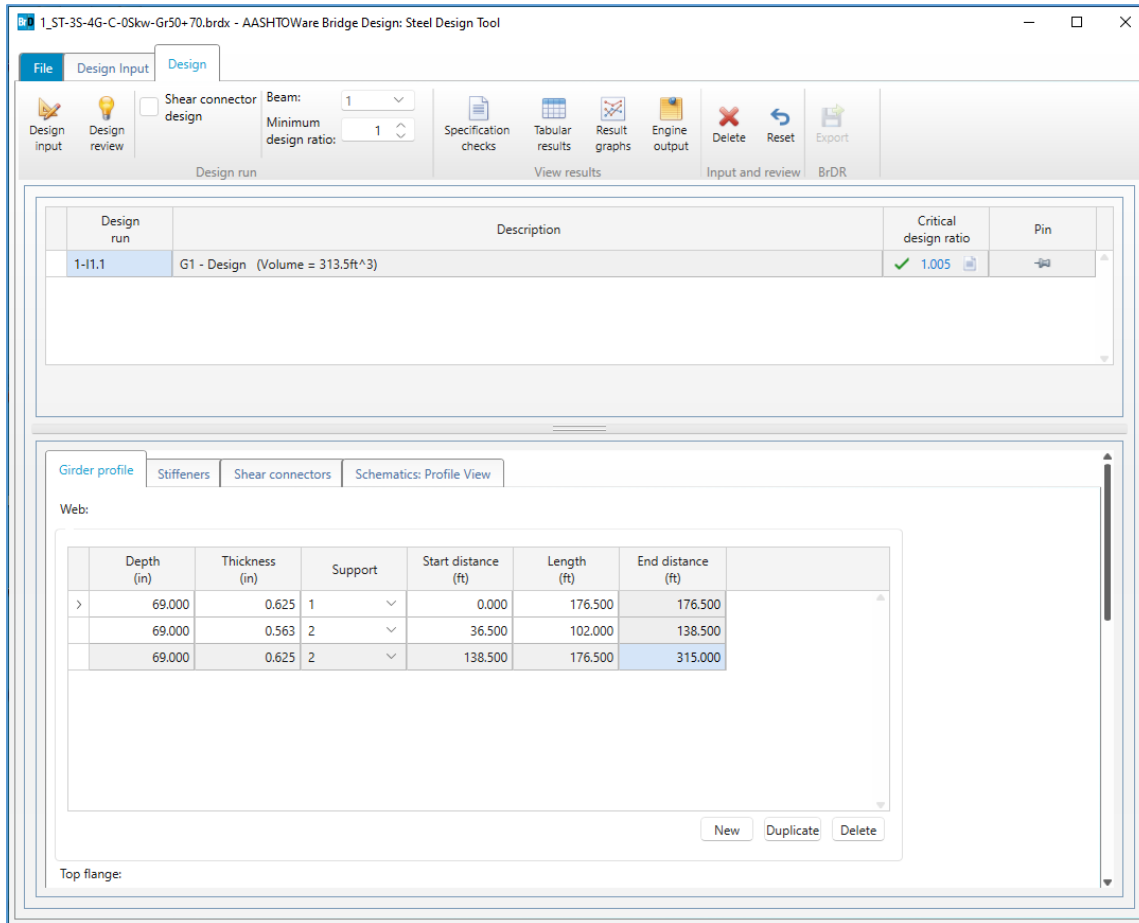
The **Design Input** tab is composed of the **Project**, **Project Library**, **Geometry**, **Deck**, **Typical Section Loads**, **Beam Parameters**, **Lateral Support**, **Member Loads**, and **Control Options** input groups as well as the **Input Report** group. The data entered in these input groups are the design inputs and parameters of the design project. The **Input Report** group shows a summary report of the design input data.

Select each of the design input groups to review the design input data.

Validation allows you turn on and off the on-the-fly design input validation. **Forward** and **Backward** provides navigation among the input groups.

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Select the **Design** tab and click on the **Design input** button  to kickoff a design input run.




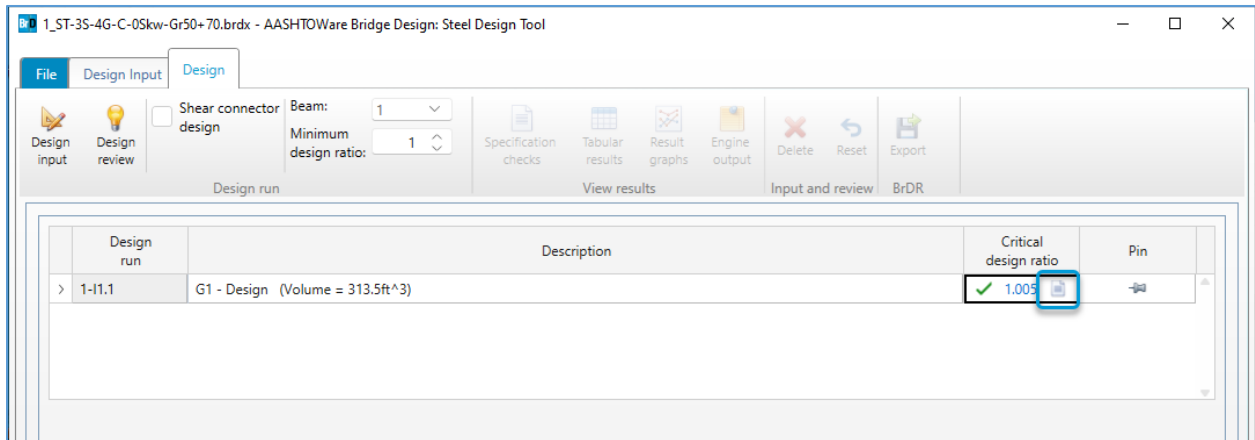
The **Design tab** is composed of the **Design ribbon**, **Design Run** table, and **Design Review** data.

The **Design** ribbon's **Design run group** is used to start a design run. A design run can be either a design input run or a design review run.

The **Design Run** table presents the beam designs for the design runs. Design run **1-11.1** signifies the beam design is for Beam 1, Design input run 1 and Iteration 1.

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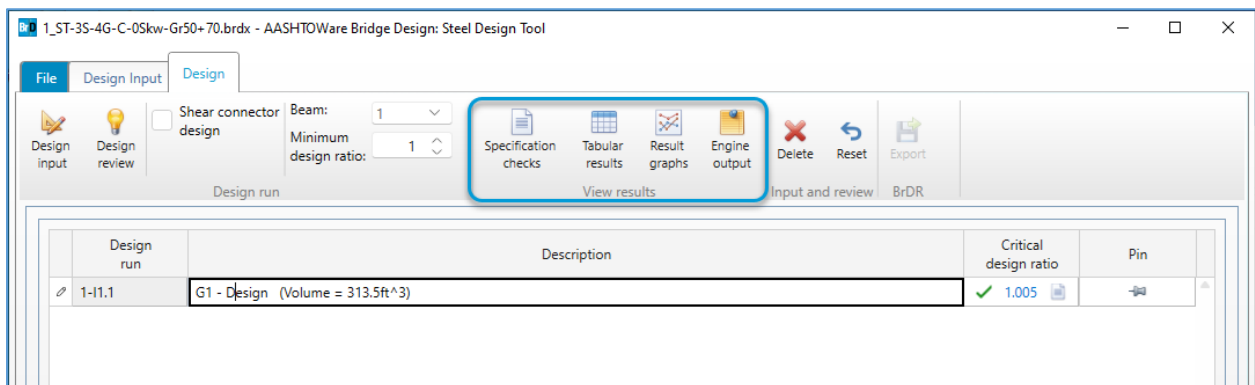
Click on the  icon next to the **Critical design ratio** to review the **Specification Checks Summary**.



The **Design Review** data represents the beam details for the selected beam design in the **Design Run** table. Details are provided for the girder profile, shear stiffeners and shear connectors (if included in the design). A profile schematic is also available. Each beam design in the **Design Run** table represents a set of **Design Input** data and a set of **Design Review** data.

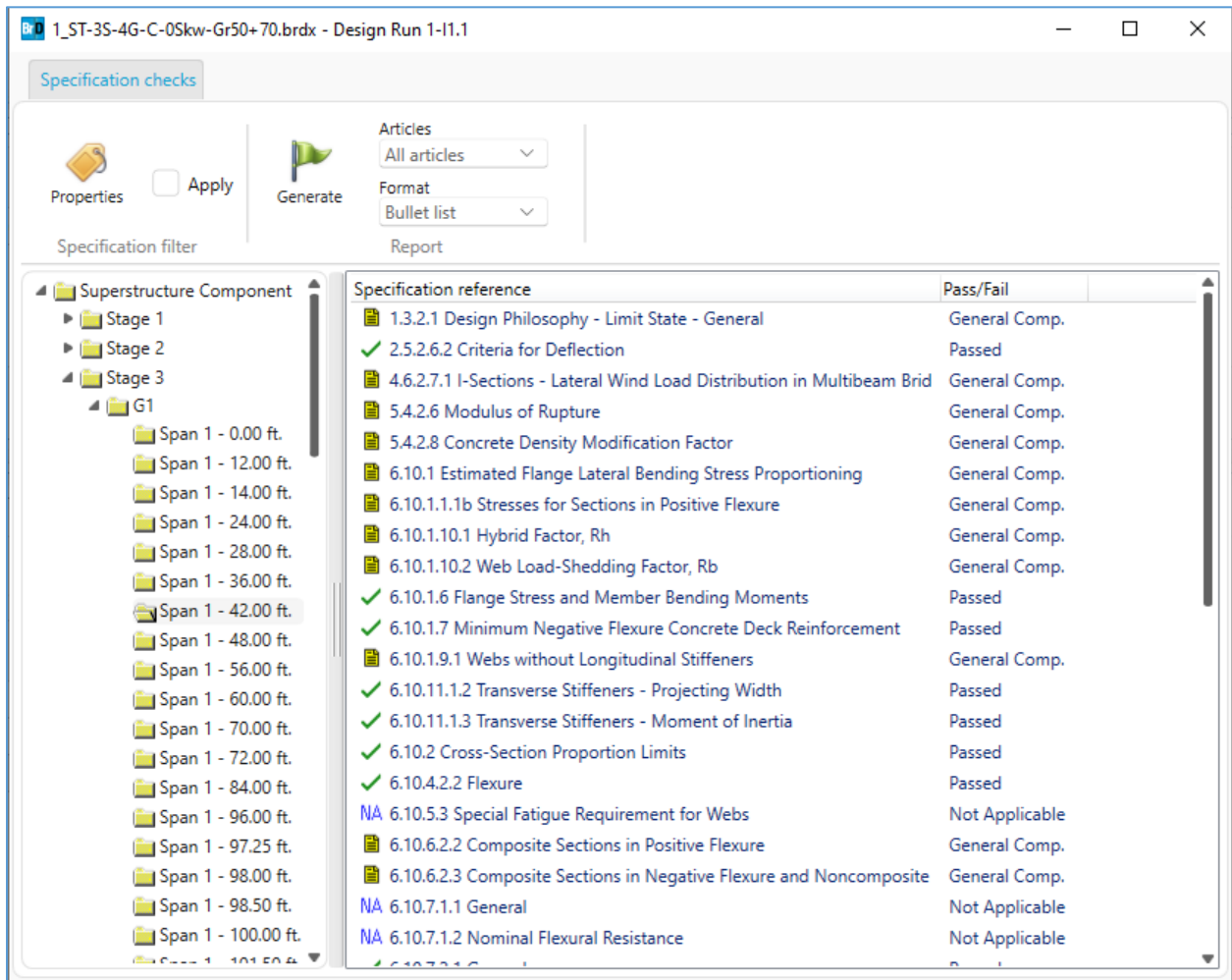
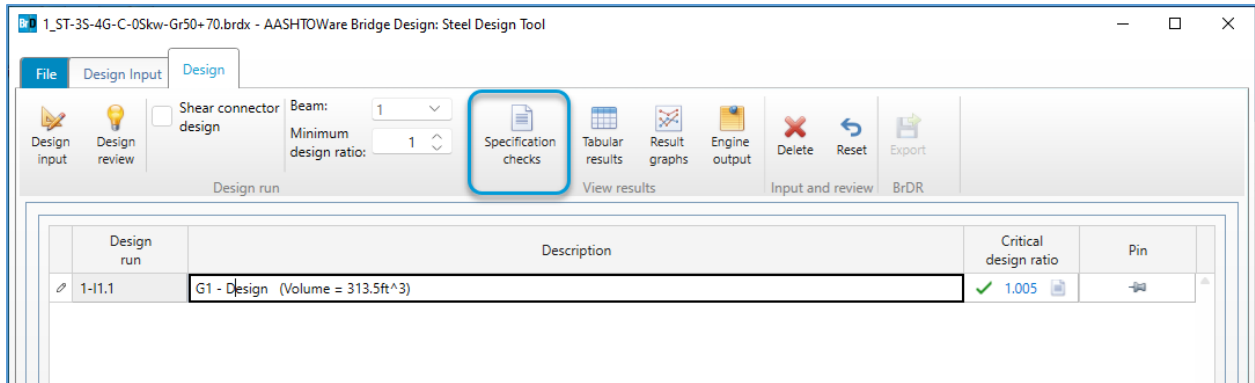
A **Design input** run uses the **Design Input** data to perform design optimization for the selected beam and the specified minimum design ratio. When a design input run is completed successfully, the optimal girder design is presented in the **Design Run** table. **Design review** run uses the **Design Input** data and **Design Review** data to perform design review for the selected beam. When a design review run is completed successfully, one girder design will be presented in the **Design Run** table.

The **Design** ribbon's **View results** group is used to open the **Specification checks**, **Tabular results**, **Result graphs**, and **Engine outputs** for the beam design selected in the **Design Run** table in the **Results** window.



Select design run **1-I1.1** and click on the **Specification checks** button to open the **Specification checks** window. Double-click on the specification articles to review the detail specification checks.

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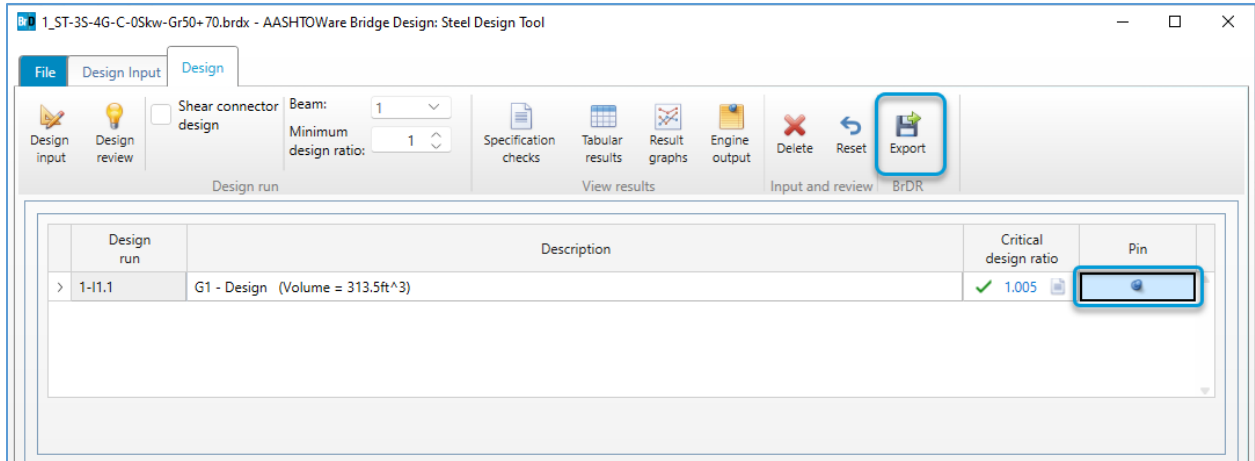


Click on the **Tabular results** button, **Result graphs** button and **Engine outputs** button to open the corresponding windows.

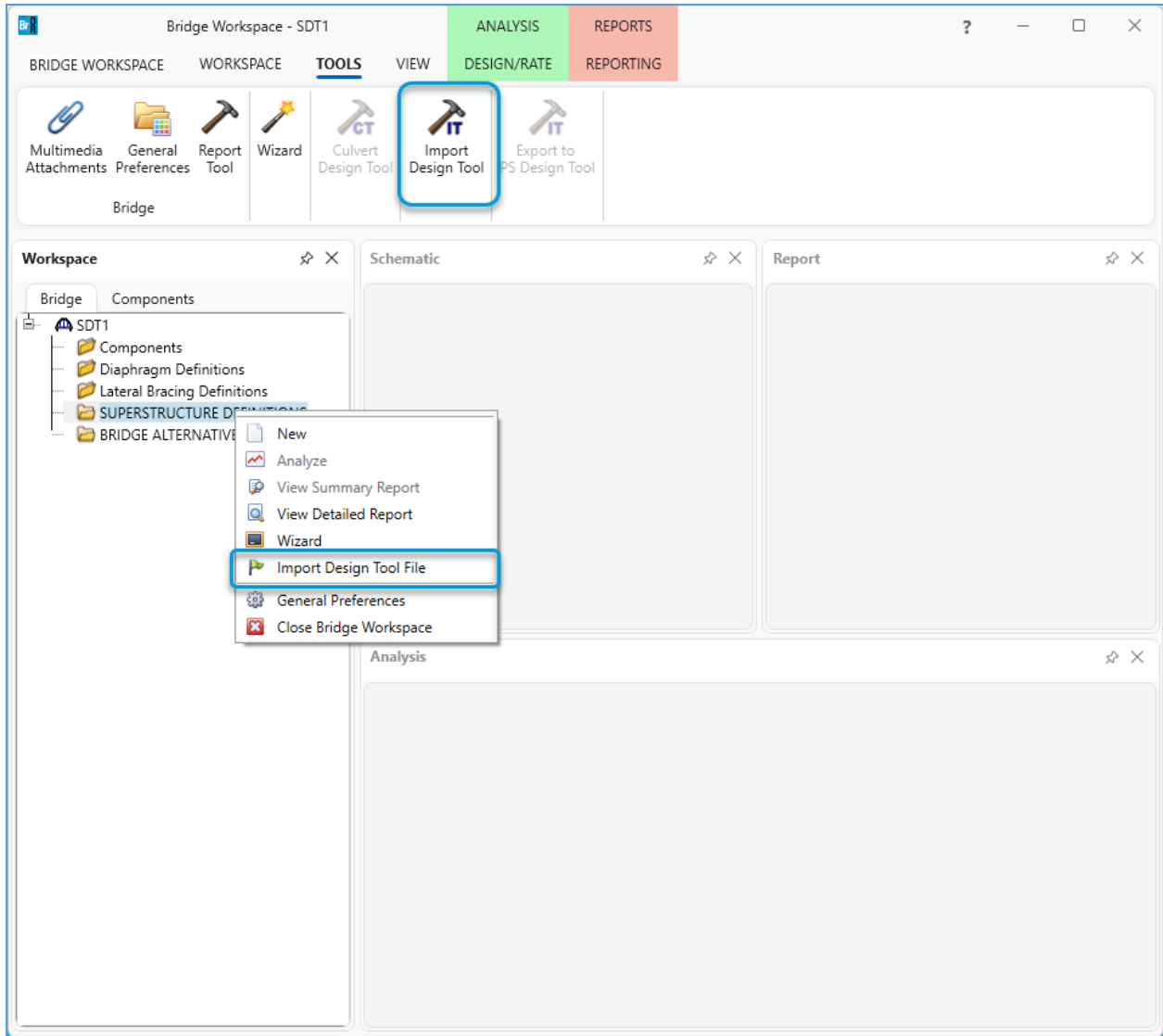
The **Design** ribbon's **Input and Review** group and **BrDR** group are used to manage the **Design Input** data and **Design review** data of the selected beam design in the Design Run table.

Export/Import functionality between Steel Design tool and BrDR

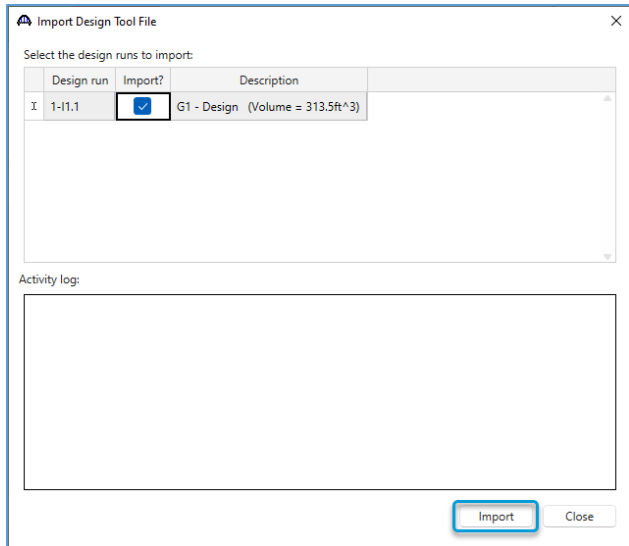
Click on the **Pin** icon to select the design run to be exported and then click on the **Export** button to export the girder design to a Bridge Design Input file (.brdi).



Launch **BrDR** and select **New** from **Bridge** tab of the **Bridge Explorer** ribbon to create a new bridge. Enter **SDT1** as the **Bridge ID** and the **NBI Structure ID**. Click **OK** to close the **Bridge Description** window. Select **SUPERSTRUCTURE DEFINITIONS** in the **Bridge Workspace** and click on the **Import Design Tool** button on the **TOOLS** ribbon (or right click on **SUPERSTRUCTURE DEFINITIONS** and click on the **Import Design Tool File** from the drop-down menu)



Select the **.brdi** file exported from the **Steel Design Tool** in the previous step. The **Import Design Tool File** window opens as shown below. Select design run **1-I1.1** import, check the **Import?** checkbox and click on the **Import** button to import the beam design into BrDR.



Click **Close** to finish importing the bridge.

Design Algorithm

The steel design tool first searches for a design which satisfies all AASHTO LRFD specifications. If an acceptable design is found, the design tool attempts to improve upon the design by reducing the section dimensions. The optimal design is the design with the smallest total steel volume with design ratios greater than the minimum design ratio entered by the user.

The steel design tool allows the user to define the range of dimensions and the increment within the range for the plate girder dimensions. For each flange, the user can input the minimum and maximum dimensions for the width and thickness. For the girder web, the user can enter the desired depth as well as the minimum and maximum web thicknesses. The user can also enter the increment by which they want each dimension to vary within the design.

Maximum Dimension Check

The first design trial always performs a maximum dimension check. It uses this initial check to determine whether a design is possible for the provided plate dimension ranges, superstructure geometry and vehicle loading. The design tool builds a trial model by assigning the maximum dimensions to the web and flange plates along the entire length of the girder. If this initial design does not satisfy the minimum design ratio criteria, the design tool will stop further design trials and output the results from this maximum dimension check. If the user encounters this situation, it is recommended they increase the web depth for the plate girder, increase the upper limits for the girder design ranges, or modify the superstructure geometry.

When establishing the plate girder dimensions for the maximum dimension trial model, the design tool may reduce some of the plate dimensions to ensure that the initial trial satisfies the proportionality limits from AASHTO LRFD 6.10.2. Often, no adjustments are required to satisfy these limits. The primary purpose of the maximum dimension check is to determine whether a solution exists with the range entered that will provide sufficient flexural capacity. This proportionality adjustment ensures the initial trial does not fail due to proportionality constraints despite having adequate flexural capacity.

After determining the dimensions for the initial trial, the design tool analyzes the girder and checks the AASHTO LRFD specifications to determine if this maximum dimension design satisfies the minimum design ratio. Proportionality, constructability, permanent deformation, flexure, and fatigue limits are checked at this point. The design tool does not review the shear criteria at this stage. The web plate thickness may provide enough shear capacity to satisfy the AASHTO LRFD shear specifications, but this condition is not required because the design tool will design web stiffeners in later design trials if the web shear capacity is not sufficient.

Initial Member Selection

The design tool uses the results from the maximum dimension check to determine the flange plate transitions and the initial plate dimensions for each of the design ranges between transitions. For girders with statically indeterminate support conditions, the transition locations are determined from the uniform load contraflexure points from the maximum dimension trial. For single span girders on simple supports, the flange transition locations are always set at 20% and 80% of the span length. In both cases, transitions are rounded to the nearest half foot. Once determined, these transition locations are used for the remainder of the design process.

There are three different ways the initial dimensions for each range are determined. If the critical design ratio for the maximum dimension check is within 10% of the minimum design ratio set by the user all the design ranges will be set the same as in the maximum dimension trial. In this case, the initial design is close enough to the design ratio limit, it is most efficient to continue from this initial set of maximum dimensions.

If the critical design ratio from the initial maximum dimension check is not close to the minimum design ratio, then the initial dimensions are determined differently for the positive flexure ranges and negative flexure ranges. For these two cases, the flange widths are set to the minimum flange widths. The web thickness is set to the minimum web thickness. For positive flexure regions, the top flange thickness is set to its minimum value and the bottom flange thickness is set to the average of the minimum and maximum value. For negative flexure, the thickness of both flanges is set to the average of the respective minimum and maximum values.

If the user enables the shear stud design option, the design tool will assign shear stud ranges to the member. When the user wants to provide studs in the negative flexure regions, the shear stud ranges extend from the end of each span to the maximum moment locations determined by applying a uniform load on the beam for the initial trial. If the user does not wish to provide studs in the negative flexure regions, the shear stud ranges extend from locations of maximum moment to zero moment.

Design Live Loads

To improve performance, the design tool implements two simplifications to the loading during the design trials. First, the design tool reuses vehicle live load results between design trials. The plate dimensions change for every design trial, but the girder span lengths, girder spacing, skew and deck geometry remain the same. Because the superstructure geometry does not change between trials and this geometry has the largest impact on live load actions, the live load results are assumed to be similar between trials. The live load analysis is a time-consuming process and this assumption reduces the total design time. For indeterminate structures, however, the structural stiffness influences the member forces. Therefore, for multi-span girder designs, the member actions from live load forces may slightly differ between trials as the girder stiffness changes. This difference can be significant enough to shift a design from passing to failing when the critical design ratio is close to the minimum design ratio. If this occurs, the design tool will recompute live load actions for each trial until the design is satisfactory.

The second modification to the live load is specific to notional vehicles with multiple load cases, such as the LRFD HL-93 design vehicle. During the design process, the load cases for each notional vehicle combination are replaced with a single envelope load case, which represents the critical results for each element in the finite element model. Both live load simplifications are used within the design process, but during the final design trial the live load is recalculated to ensure the final design is satisfactory.

Design Process

The steel design tool checks the AASHTO LRFD specifications for each design trial. If any criteria fail, then the design tool increases the appropriate dimension until those criteria are met. The design tool works in the following order:

- | | |
|--------------------------|-------------------------------------|
| 1. Proportionality | LRFD 6.10.2 |
| 2. Constructability | LRFD 6.10.3 |
| 3. Permanent Deformation | LRFD 6.10.4 |
| 4. Flexure | LRFD 6.10.7, 6.10.8, APP A6, APP B6 |
| 5. Shear | LRFD 6.10.9 |
| 6. Fatigue | LRFD 6.6.1.2.2, 6.10.5.3 |

The design tool first checks the proportionality requirements. It will continue to increase section dimensions and re-evaluate the girder until all proportionality constraints are satisfied. The tool then considers constructability. If any updates are made to satisfy constructability limits, the design returns to the proportionality checks to ensure those requirements are still satisfied. Once both proportionality and constructability limits are satisfied, the tool moves on to the short-term section, where permanent deformation, flexure and shear are designed. Again, if any updates are made to satisfy short-term section requirements, the design tool returns to check previous proportionality and constructability requirements. The design tool repeats this process again for the fatigue requirements. If the design options for appendix A6 or moment redistribution are selected by the user, the design tool will modify the girder sections to satisfy the relevant LRFD requirements to use these analysis methods. The appendix A6 requirements are checked prior to designing for the short-term section requirements and the moment redistribution requirements are checked after designing for shear and stiffeners but prior to designing for flexure. With each section update, the design tool recomputes the dead load actions using the updated girder dimensions.

When the design tool conducts shear design, bearing stiffeners are added to the support locations. The bearing stiffeners are designed based on article 6.10.11.2.

When the user opts to not use transverse stiffeners, no transverse stiffeners will be added to the steel girder. The design tool will check the shear limit for all the points of interest along the girder length. If the shear requirement is not met,

the web thickness will be increased, and the shear requirement will be re-evaluated. This process is repeated until the shear requirement is met.

When the user opts to use transverse stiffeners, the design tool will check the shear limit for all the points of interest along the girder length. If the shear requirement is not satisfied, the web thickness will be increased, and the shear requirement will be re-evaluated. If the web thickness reaches the maximum dimension entered by the user and the shear requirement is still not satisfied, the design tool will add transverse stiffeners to increase shear resistance. Otherwise, no transverse stiffeners will be added. The transverse stiffeners will first be added to the diaphragm locations (if exterior diaphragms exist). Then, the shear limit will be checked at supports. If the shear requirement is not satisfied at supports, transverse stiffeners will be added to form the end panels. After that, the design tool will add interior transverse stiffeners if the shear requirement is not satisfied for any point of interest along the girder length. If there are stiffeners that are too close to each other, the design tool will increase the spacing between the stiffeners based on the minimum spacing requirement, which is determined based on LRFD equation 6.10.9.3.2-4.

When increasing section dimensions, the design tool uses the increment defined by the user. The update methods also utilize information about the current and minimum design ratios to take larger steps when appropriate to speed up convergence. For each design trial, the design tool will merge adjacent ranges for webs or flanges if the respective dimensions are the same.

If the design tool reaches one of the upper limits and is still unable to satisfy the design requirements, the design tool will stop further design trials and return the best available design. At early stages in the design process, the best design may be the maximum dimension trial because this is the only design which satisfies all of the LRFD specifications.

Minimizing Design Weight

For most configurations, there may be many possible girder designs which have design ratios close to the minimum design ratio. The design tool searches for the design in this set which has the lowest total steel volume. Steel volume is assumed to provide a good estimate for the cost of a particular design and is directly proportional to the total weight of the girder.

When the design tool finds a design that meets all of the LRFD requirements, it computes the steel volume for this successful design trial. The design tool then reduces the plate girder dimensions and redesigns the girder. If multiple successful trials are available, the design tool uses the information from the previous design ratios and input dimensions to inform the section reduction, otherwise all dimensions are reduced by one step.

After redesigning each reduced section, the reduced section volume is compared with the previous volume. While the section volume is decreasing, the design is improving. Once the volume stops decreasing, the design tool has found a minimum point, which it considers to be the optimal design.

Final Design Check

A final design trial with the full live load is performed on the optimal design. During this step, if the user enables the shear stud design option, the shear stud wizard is used to develop the shear stud patterns. Placeholder studs set for the initial ranges are replaced with the actual designed shear stud. If the shear stud design tool is unable to find a design, the top flange widths are increased until a design can be found.

The design tool determines the best design which can be achieved by modifying the design variables, such as the plate dimensions. Occasionally, the final design may fail a specification article that cannot be readily fixed by modifying the design variables. In these cases, it is recommended the user review the specification results and adjust their inputs accordingly. One example is the LRFD 6.10.1.7 specification for minimum negative flexure concrete deck reinforcement. If this article fails, the user should revisit the inputs for the deck reinforcement and increase the rebar in negative flexure regions to satisfy the minimum steel area requirements.