AASHTOWare Bridge Design Training

Weld Design and Weld Fatigue Analysis (BrD 6.5)

Topics Covered

- Flange to web weld LRFD Design
- Flange to web weld LRFD Design Review
- Weld Fatigue Analysis

Part 1: Weld Design/Design Review

Using BID1 in the sample bridge database, the step by step process of fillet weld design at flange-web junction of a scheduled based plate girder is described below.

Weld Design & Design Review Steps

Step 1- Open BID1:

Open Bridge Design (BrD) 6.5 and then open TrainingBridge1 (BID1)

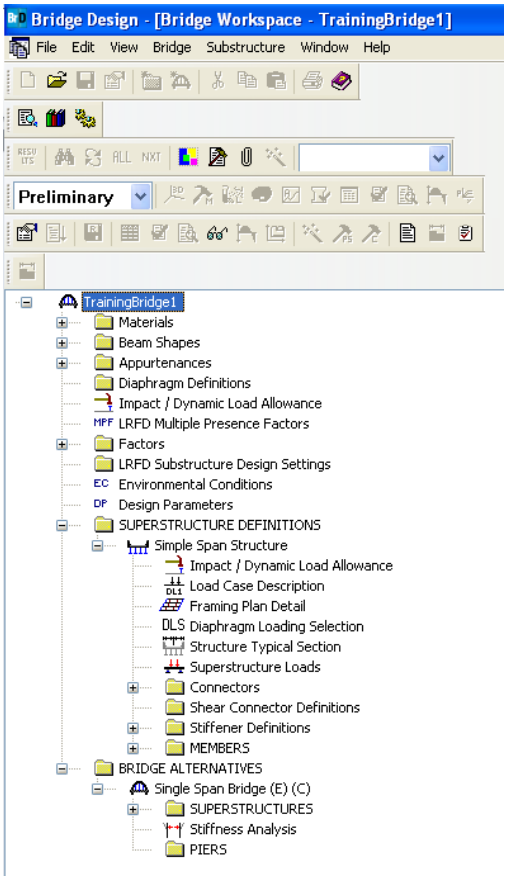

Figure 1

Step 2- Open Weld Definitions:

Expand the “Simple Span Structure” under SUPERSTRUCTURE DEFINITIONS and then expand Connectors. Open Weld Definitions.

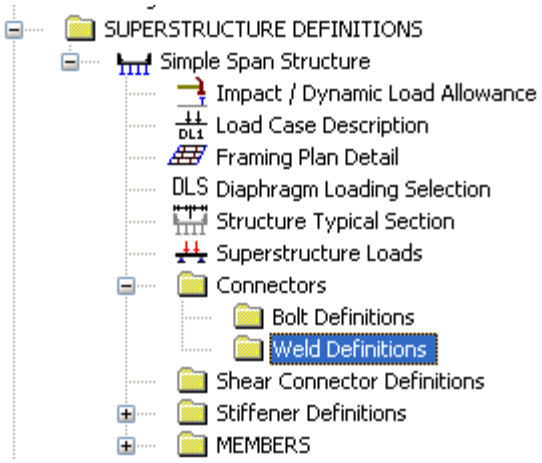

Figure 2

Step 3- Define Weld:

For weld *design* of top flange – web fillet weld:

Leave the “Weld size” field blank to be designed as per LRFD article 6.13.3.2.4 (Weld Design). After entering all the fields shown below, click on the “Copy Values from Library...” button to populate the “Electrode Strength” of the weld fields. Click “OK” to save the data.

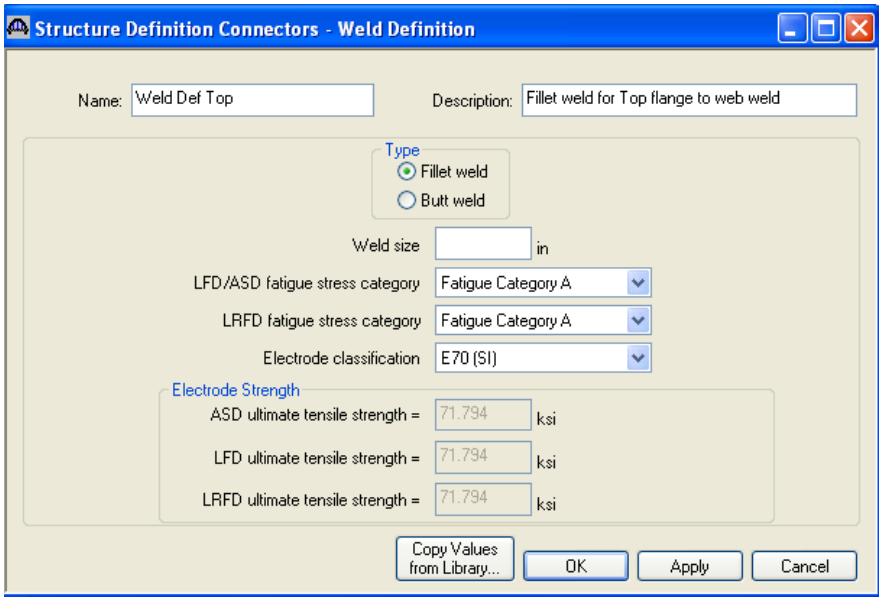

Figure 3

For weld *design review* of bottom flange – web fillet weld:

Open Weld Definitions again (repeat step 2) and repeat Step 3 to define “Weld Def. Bottom”. Indicate a value in the Weld Size field for it to undergo design review as per LRFD article 6.13.3.2.4. Click “Ok” to save the definition.

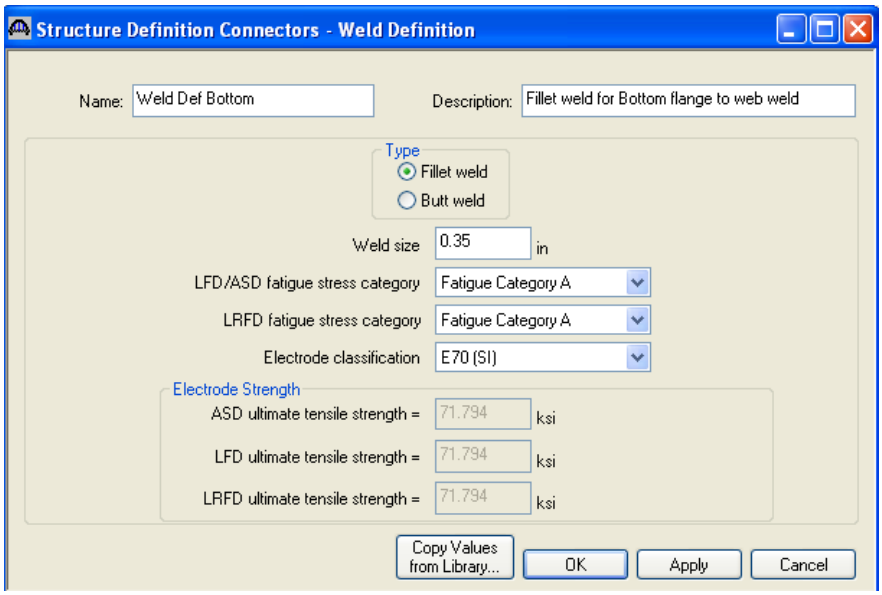

Figure 4

The Connectors->Weld Definitions->”Weld Def. Top” & “Weld Def. Bottom” as defined should reflect on the “Simple Span Structure” tree as shown below.

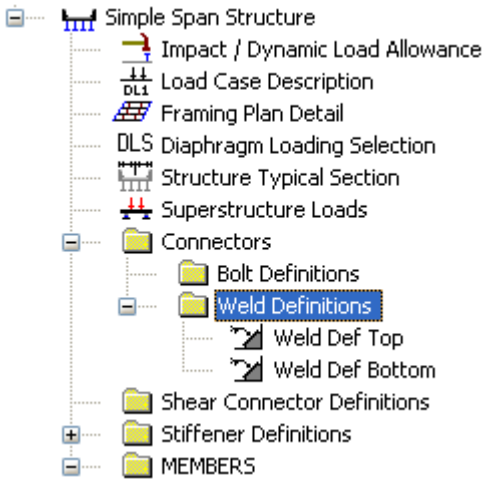

Figure 5

Step 4- Navigate to girder profile:

Navigate to MEMBERS and expand it. Expand “G1” and then expand MEMBER ALTERNATIVES. Expand “Plate Girder” as shown below and open Girder Profile.

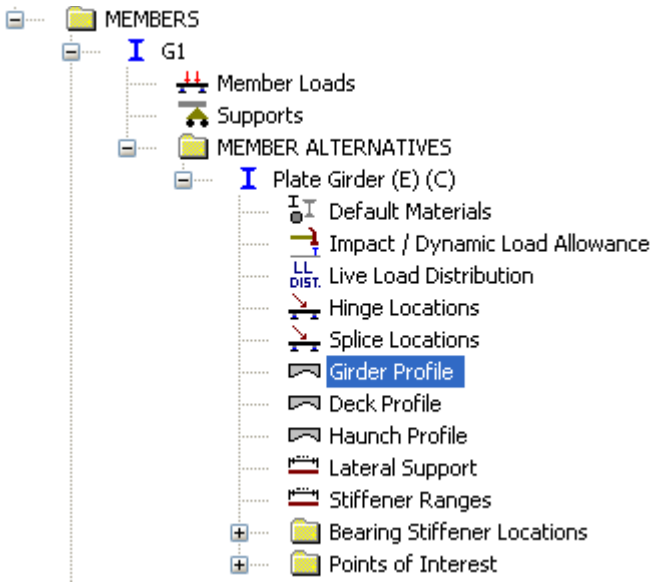

Figure 6

Step 5- Allocate flange - web weld definition:

For Top Flange the "*Weld"* field select "Weld Def. Top" from the dropdown as shown below. This will design the top flange-web fillet weld for the range of the top flange plate indicated below.

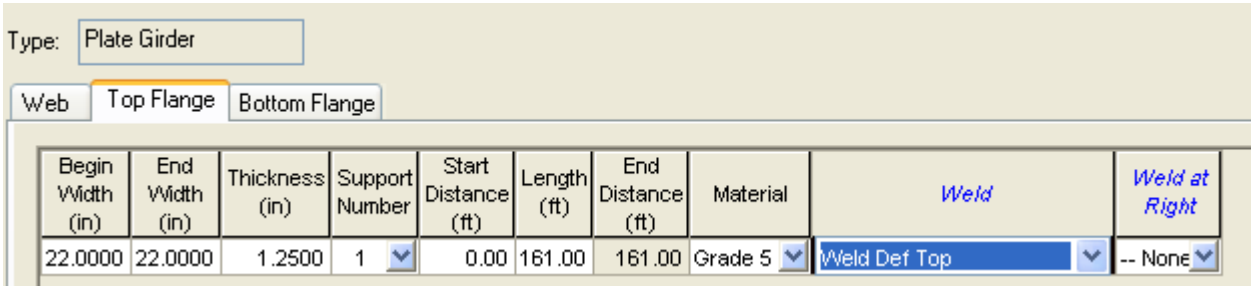

Figure 7

Repeat the same process for the bottom flange as shown below

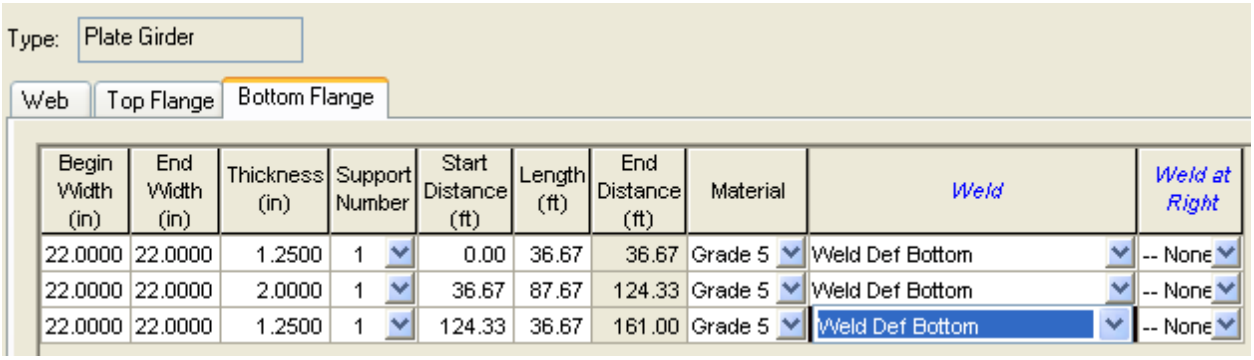

Figure 8

Please note that the same definition can be used for both the top and bottom flange to web welds provided that both the weld definitions are either undergoing design or design review. Similarly different weld definitions can also be used for different ranges of top and bottom flange plates.

Click "OK" to save the details of allocation.

Step 6- Define Analysis Settings:

Click on View Analysis Settings button

Figure 9

Click on Open Template and select "HL 93 Design Review" as shown below and click Open:

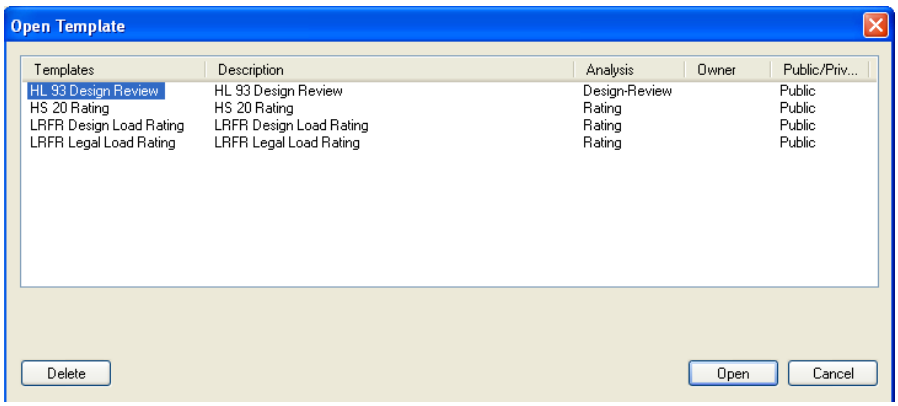

Figure 10

The Analysis Settings window should be seen as below. Click OK to save the settings.

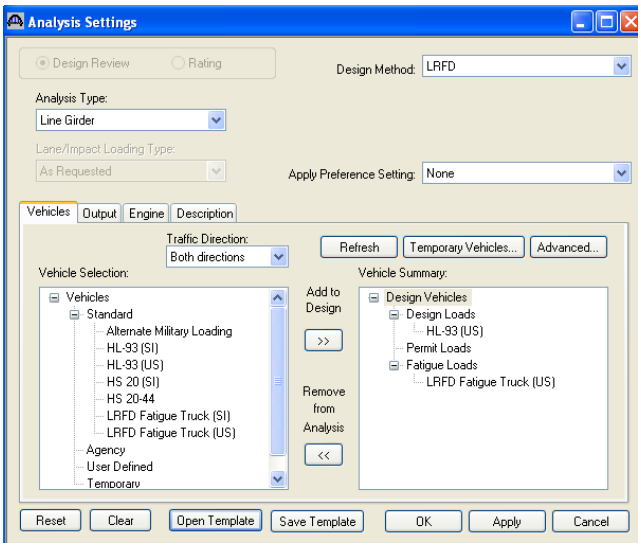

Figure 11

Step 7- Analyze G1 – Plate Girder:

Right click on “Plate Girder” and Select Analyze.

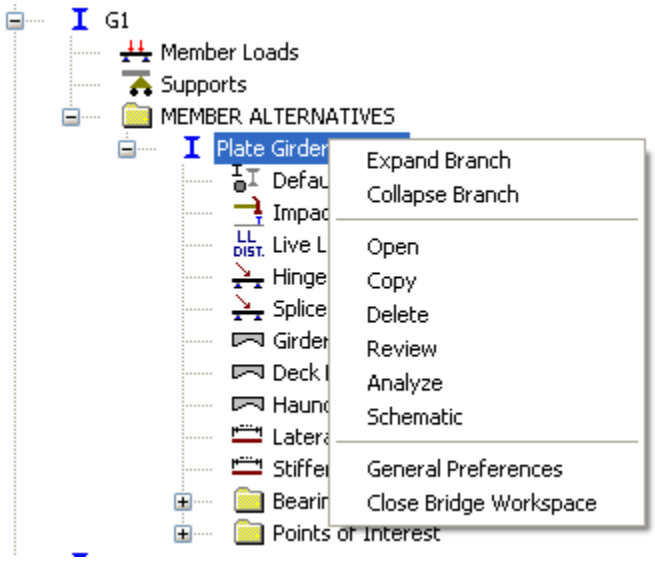

Figure 12

Step 8- View Spec Check for LRFD article 6.13.3.2.4

After the analysis gets completed click on the button “View Spec Check” to open the Specification check window (with the “Plate Girder” highlighted as shown above).

Figure 13

Navigate to Superstructure Component->Stage 3->Plate Girder-> Span 1 – 64.4 ft. (this is a representative point for demonstration; you can navigate to any other spec check point you wish to check).

Open article 6.13.3.2.4 Fillet Welded Connections as shown below:

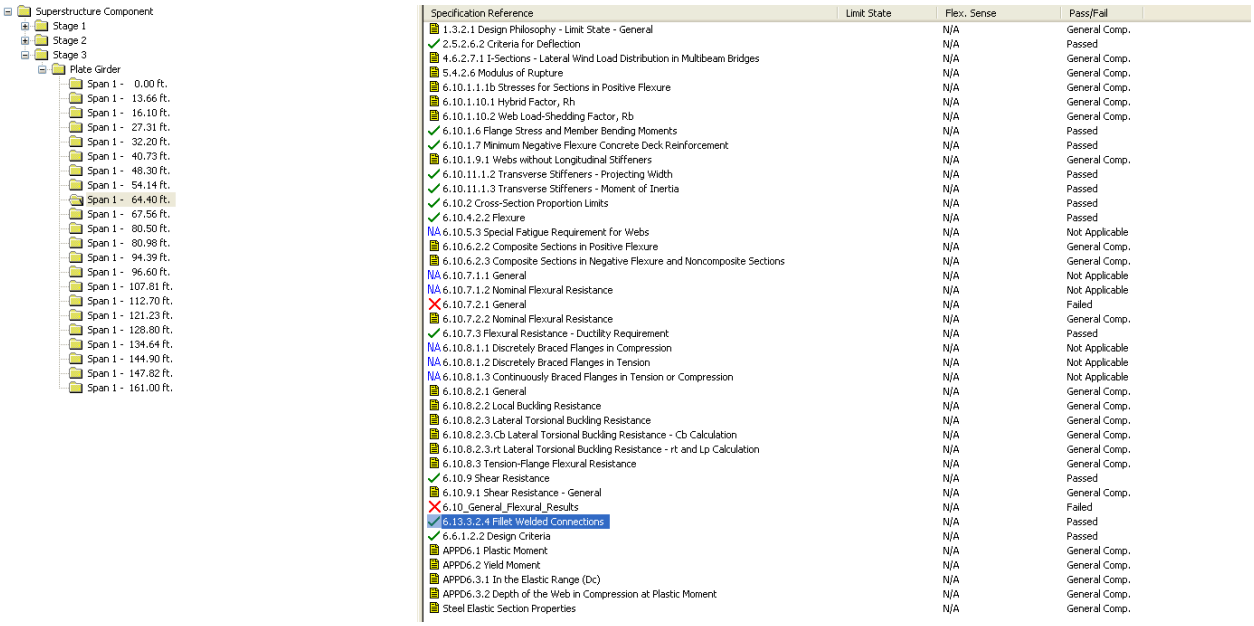

Figure 14

Weld details for top and bottom flange to web welds are provided as below. Note that the Top flange weld size is not visible since it has been designed and shown below.

```
Top flange to web weld
----------------------
Fexx       =   71.7937 (ksi)
Phie2      =    0.8000

Bottom Flange to Web Weld
-------------------------
Fexx       =   71.7937 (ksi)
Phie2      =    0.8000
Weld size  =    0.3500 (in)
```

Figure 15

The weld resistances for the top and the bottom flange are shown below:

```
SUMMARY:

Weld Metal Resistance (top flange):
Rr = 0.6*Phie2*Fexx =  34.4610 (ksi)                (6.13.3.2.4b-1)

Weld Metal Resistance (bottom flange):
Rr = 0.6*Phie2*Fexx =  34.4610 (ksi)                (6.13.3.2.4b-1)
```

Figure 16

Fillet-weld *design* for the top flange to web:

Design Step 1: Allowable weld size was determined as per the strength criteria as shown in the tables below. Please note that thickness and size have the same meaning here.

$$\text{Required weld thickness} = \frac{v\ (\text{total})}{Rr * \text{Sqrt}(2)}$$

Factored load computation for weld design (top flange):

Limit State	Flex Type	VDL Stage 1 (kip)	vDL Stage 1 (kip/in)	VDL Stage 2 (kip)	vDL Stage 2 (kip/in)
STR-I	Pos	37.22	0.42	11.73	0.15
STR-I	Pos	26.80	0.30	6.54	0.09
STR-I	Pos	37.22	0.42	11.73	0.15
STR-I	Pos	26.80	0.30	6.54	0.09
STR-III	Pos	37.22	0.42	11.73	0.15
STR-III	Pos	26.80	0.30	6.54	0.09
STR-III	Pos	37.22	0.42	11.73	0.15
STR-III	Pos	26.80	0.30	6.54	0.09
STR-V	Pos	37.22	0.42	11.73	0.15
STR-V	Pos	26.80	0.30	6.54	0.09
STR-V	Pos	37.22	0.42	11.73	0.15
STR-V	Pos	26.80	0.30	6.54	0.09

Limit State	Flex Type	Load Combo	VLL (kip)	vLL (kip/in)	vtotal (kip/in)	Required Weld Size(Strength) (in)	Design Ratio	Code
STR-I	Pos	1	124.24	1.71	2.29	0.0469	1.00	Pass
STR-I	Pos	1	72.29	1.00	1.38	0.0284	1.00	Pass
STR-I	Pos	2	101.61	1.40	1.97	0.0405	1.00	Pass
STR-I	Pos	2	59.99	0.83	1.22	0.0249	1.00	Pass
STR-III	Pos	1	0.00	0.00	0.57	0.0117	1.00	Pass
STR-III	Pos	1	0.00	0.00	0.39	0.0079	1.00	Pass
STR-III	Pos	2	0.00	0.00	0.57	0.0117	1.00	Pass
STR-III	Pos	2	0.00	0.00	0.39	0.0079	1.00	Pass
STR-V	Pos	1	95.84	1.32	1.90	0.0389	1.00	Pass
STR-V	Pos	1	55.77	0.77	1.16	0.0237	1.00	Pass
STR-V	Pos	2	78.39	1.08	1.65	0.0339	1.00	Pass
STR-V	Pos	2	46.28	0.64	1.03	0.0210	1.00	Pass

Figure 17

Design Step 2: The weld size was optimized using article 6.13.3.4 as shown below to provide the final designed weld size for the top flange to web weld.

Designed top flange fillet weld size:

Article 6.13.3.4

Maximum fillet weld size allowed = 0.4375 (in)

Minimum fillet weld size allowed = 0.3125 (in)

Design fillet weld size at the top flange = 0.3125 (in)

Figure 18

Fillet -weld *design review* for the bottom flange to web:

Design Review Step 1: Bottom flange weld size (which was provided) was reviewed as per article 6.13.3.4 (allowable weld size) as shown below:

```
Bottom Flange Weld:
-------------------
Throat(eff)       =   0.2475 (in)
Area(eff)         =   0.4950(in^2/in)
Weld Resistance   =   Rr*A(eff)
Weld Resistance   =  17.0573(kip/in)

Article 6.13.3.4:
Maximum weld size allowed =    0.4375 (in)          Pass
Minimum weld size allowed =    0.3125 (in)          Pass
```

Figure 19

Design Review Step 2: Bottom flange weld size specification check was performed

Specification Check for bottom flange-web weld:

Limit State	Flex Type	VDL Stage 1 (kip)	vDL Stage 1 (kip/in)	VDL Stage 2 (kip)	vDL Stage 2 (kip/in)
STR-I	Pos	37.22	0.49	11.73	0.13
STR-I	Pos	26.80	0.35	6.54	0.07
STR-I	Pos	37.22	0.49	11.73	0.13
STR-I	Pos	26.80	0.35	6.54	0.07
STR-III	Pos	37.22	0.49	11.73	0.13
STR-III	Pos	26.80	0.35	6.54	0.07
STR-III	Pos	37.22	0.49	11.73	0.13
STR-III	Pos	26.80	0.35	6.54	0.07
STR-V	Pos	37.22	0.49	11.73	0.13
STR-V	Pos	26.80	0.35	6.54	0.07
STR-V	Pos	37.22	0.49	11.73	0.13
STR-V	Pos	26.80	0.35	6.54	0.07

Limit State	Flex Type	Load Combo	VLL (kip)	vLL (kip/in)	vtotal (kip/in)	Required Weld Size(Strength) (in)	Design Ratio	Code
STR-I	Pos	1	124.24	1.32	1.94	0.0399	8.77	Pass
STR-I	Pos	1	72.29	0.77	1.20	0.0245	14.26	Pass
STR-I	Pos	2	101.61	1.08	1.70	0.0350	10.01	Pass
STR-I	Pos	2	59.99	0.64	1.07	0.0219	16.01	Pass
STR-III	Pos	1	0.00	0.00	0.62	0.0128	27.37	Pass
STR-III	Pos	1	0.00	0.00	0.43	0.0088	39.93	Pass
STR-III	Pos	2	0.00	0.00	0.62	0.0128	27.37	Pass
STR-III	Pos	2	0.00	0.00	0.43	0.0088	39.93	Pass
STR-V	Pos	1	95.84	1.02	1.64	0.0337	10.38	Pass
STR-V	Pos	1	55.77	0.59	1.02	0.0209	16.72	Pass
STR-V	Pos	2	78.39	0.83	1.46	0.0299	11.71	Pass
STR-V	Pos	2	46.28	0.49	0.92	0.0189	18.55	Pass

Figure 20

For article 6.13.3.2.4 to pass, weld design (top flange) and weld design review (bottom flange) should both “Pass”.

Close the bridge BID1 without saving it.

Part 2: Weld Fatigue Analysis

Table 1: Weld Fatigue Analysis Detail

Fatigue Detail	Conditions for Generation	Fatigue Category
Web to flange weld	Detail automatically generated at every analysis point for plate girders.	Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld definition' window. Otherwise, determined from the Specification.
Plate girder flange groove welded butt splices	Detail automatically generated at every analysis point where condition exists. Analysis point at transition is generated if user picks 'Generate at section change points'.	Schedule based beams: Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld Definition' window. Otherwise, determined from the Specification. Cross Section based beams: Determined from the Specification since the user cannot assign a weld definition.
Bearing stiffener weld to top/bottom flange	• Analysis point generated at every bearing stiffener location at an offset distance from the C.L. of bearing specified by the user on the 'Bearing Stiffener Location' window if user picked 'Generate at stiffeners' • Detail only generated if 'Top' or 'Bottom' flange welds are defined on the 'Bearing Stiffener Definition' window	Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld Definition' window.
Bearing stiffener weld to web	• Analysis point generated at every bearing stiffener location	Category based on the 'LRFD fatigue stress category' defined

	at an offset distance from the c.l. of bearing specified by the user on the 'Bearing Stiffener Location' window if user picked 'Generate at stiffeners' • Detail automatically generated at every analysis point where stiffener exists	on the 'Structure Definition Connectors – Weld Definition' window. Otherwise, determined from the Specification.
Transverse stiffener weld to top/bottom flange	• Analysis point generated at every stiffener location defined on the 'Stiffener Ranges' window if user picked "Generate at stiffeners' • Detail only generated if the 'Top' or 'Bottom' flange welds are defined on the 'Transverse Stiffener Definition' • Detail not generated at the respective flanges if the 'Top Gap' or 'Bottom Gap' user input on the 'Transverse Stiffener Definition' window is greater than zero	Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld Definition' window.
Transverse stiffener weld to web	• Analysis point generated at every stiffener location if user picked "Generate at stiffeners' • Detail automatically generated at every analysis point where stiffener exists • Distance to the fatigue detail from the top or bottom of web is based on the user input 'Top Gap' and /or 'Bottom Gap' on the 'Transverse Stiffener Definition' window. If the values are left blank, the distance is considered to be 0.0	Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld Definition' window. Otherwise, determined from the Specification.

Shear stud weld to top flange	• Detail automatically generated at every analysis point where shear connectors exist • Detail is only generated if a defined shear connector is used. The detail will not be generated for ranges where "Composite" is chosen as the Connector ID	Determined from the Specification.
Longitudinal Stiffeners	• Analysis point generated at the start and end of the stiffener if user picked 'Generate at stiffeners' • Detail automatically generated at every analysis point where a plate longitudinal stiffener exists	• Category at the start and end of the stiffener is determined from the Specification • Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld Definition' window. Otherwise, determined from the Specification
Welded cover plates	• Analysis point at start and end of cover plate is generated if user picks 'Generate at section change points' • Start and end cover plate detail automatically generated at every analysis point where a welded cover plate starts or ends • Cover plate side weld detail automatically generated at every analysis point that contains a welded cover plate	Category based on the 'LRFD fatigue stress category' defined on the 'Structure Definition Connectors – Weld Definition' window. Otherwise, determined from the Specification.

The above table provides the list of location stating when and where the weld fatigue analysis is carried out.

The fatigue analysis of flange butt welds and welded cover plates at the start/end can be obtained by editing the Member Alternative Name->Control Options->LRFD->Point of Interest-> “Generate at section change points” as shown below.

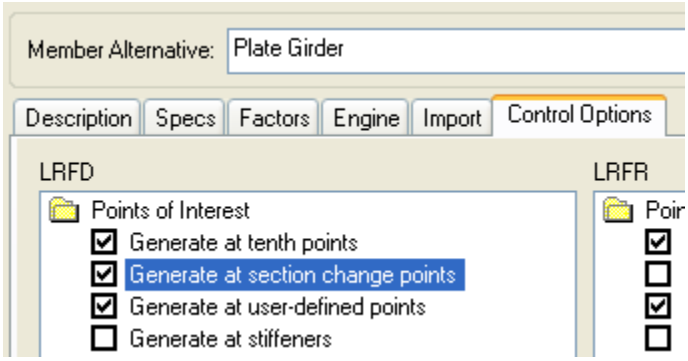

Figure 21

A new Control Option “Generate at Stiffeners” under Point of Interest has been added for v6.5 to generate the analysis point at the locations of transverse, bearing and at the start and at the end point of longitudinal stiffeners.

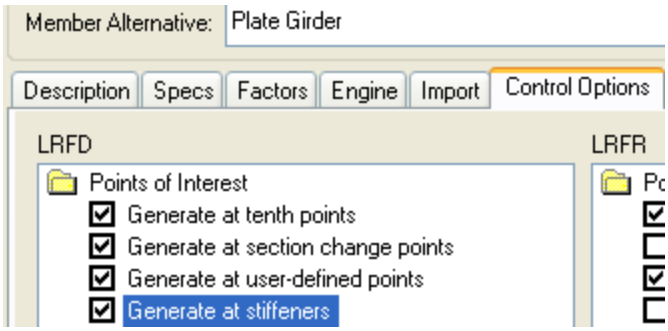

Figure 22

Open BID1 and define a weld definition as defined in page 3 of this document. Assign the LRFD Fatigue Category as “Fatigue Category C’”. Open the transverse stiffener definition (Stiffener) and assign the weld definition as shown below.

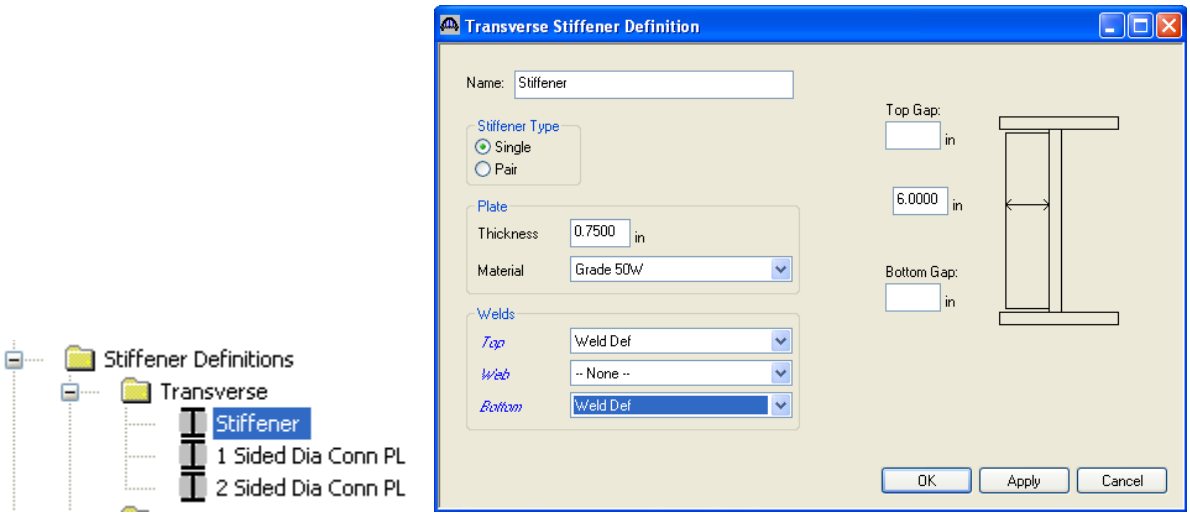

Figure 23

Before running the LRFD design review of a Member G1, Member Alternative: Plate Girder, make sure that you have the Control Options selected for "Generate at Stiffeners"

After the LRFD design review, Spec check at Stage 3->Plate Girder->Span 1 – 16.08 ft., article 6.6.1.2.2 Design Criteria. This is a location of transverse stiffener.

As shown below, the article shows the fatigue analysis for transverse stiffener to web weld (fatigue category from specification), for transverse stiffener to flange weld (fatigue category defined) and flange to web weld (fatigue category from specification).

.

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	Stress DL (ksi)	Stress +LL (ksi)	Stress -LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
TranStiffFlgWeld	C'	745	1211.05	0.00	FAT-I	70.25	-11.88	-0.72	0.00***	---	---	---	---	---	---
TranStiffFlgWeld	C'	745	1211.05	0.00	FAT-I	1.25	13.48	4.93	0.00	44.00	12.00	12.00	4.93	2.44	PASS
TranStiffWebWeld	C'	745	1211.05	0.00	FAT-I	70.25	-11.88	-0.72	0.00***	---	---	---	---	---	---
TranStiffWebWeld	C'	745	1211.05	0.00	FAT-I	1.25	13.48	4.93	0.00	44.00	12.00	12.00	4.93	2.44	PASS
TopFlgWebWeld	B	860	1211.05	0.00	FAT-I	70.25	-11.88	-0.72	0.00***	---	---	---	---	---	---
BotFlgWebWeld	B	860	1211.05	0.00	FAT-I	1.25	13.48	4.93	0.00	120.00	16.00	16.00	4.93	3.25	PASS

Figure 24

Close the BID1 and open BID2

Define a bearing stiffener to flange weld with LRFD fatigue category C'. Assign the weld definition to the top and the bottom flange as shown below

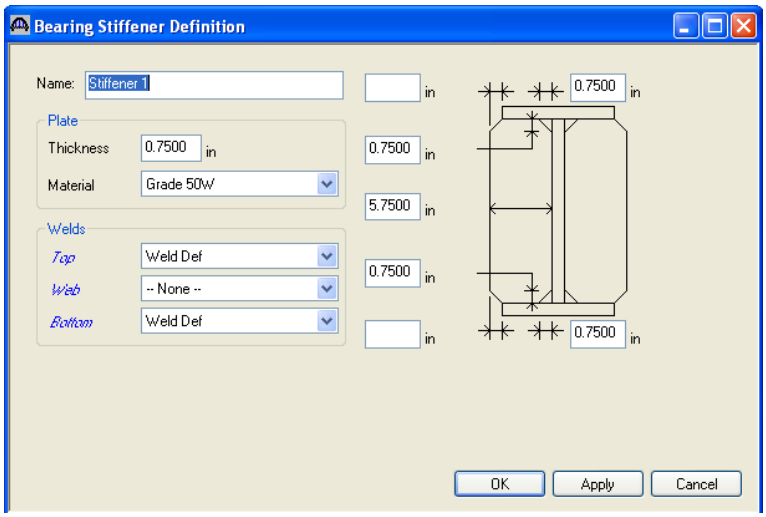

Figure 25

For Cross Sections -> Section2, add a top cover plate as shown below

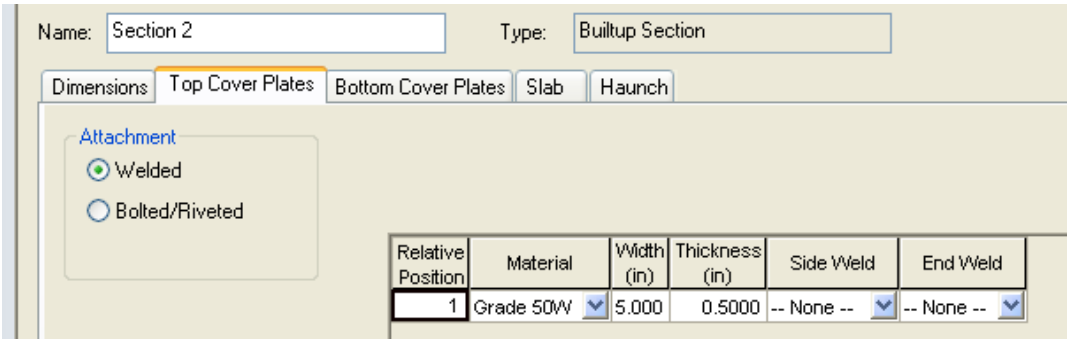

Figure 26

Define a plate longitudinal stiffener as shown below

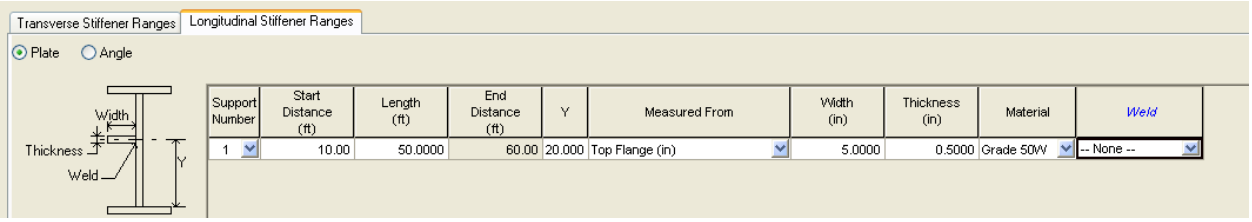

Figure 27

Before running the LRFD design review of Interior Member, Member Alternative: Built-up Alt, make sure that you have the Control Options selected for “Generate at Stiffeners” and “Generate at section change points”.

After the LRFD design review, Spec check for article 6.6.1.2.2 Design Criteria.

Spec check at Stage 3->Built-up Alt->Span 1 63 ft. (left)

This shows the fatigue analysis of flange and web groove weld and shear connector welds to the top flange as shown below. All the fatigue categories are from specification.

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	Stress DL (ksi)	Stress +LL (ksi)	Stress -LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
FlgWeldAtRight	B	860	423.56	-297.63	FAT-I	37.63	-0.80	-0.29	4.62	120.00	16.00	16.00	4.92	3.25	PASS
FlgWeldAtRight	B	860	423.56	-297.63	FAT-I	0.00	1.09	6.13	-5.57	120.00	16.00	16.00	11.70	1.37	PASS
WebWeldAtRight	B	860	423.56	-297.63	FAT-I	36.88	-0.76	-0.16	4.42	120.00	16.00	16.00	4.59	3.49	PASS
WebWeldAtRight	B	860	423.56	-297.63	FAT-I	0.88	1.05	5.98	-5.33	120.00	16.00	16.00	11.31	1.41	PASS
ShearConnector	C	1290	423.56	-297.63	FAT-I	37.63	-0.80	-0.29	4.62	44.00	10.00	10.00	4.92	2.03	PASS

Figure 28

Speck check at Stage 3->Built-up Alt->Span 1 89.5 ft. (left)

This shows the fatigue analysis of bearing stiffener top and bottom flange (fatigue category defined) and the web weld (fatigue category from spec).

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	Stress DL (ksi)	Stress +LL (ksi)	Stress -LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
BrgStiffFlgWeld	C'	496 +	0.00	-422.82	FAT-I	37.50	23.77*	0.00	3.59	44.00	12.00	12.00	3.59	3.34	PASS
BrgStiffFlgWeld	C'	496 +	0.00	-422.82	FAT-I	1.50	-21.48*	0.00	-4.50***	---	---	---	---	---	---
BrgStiffWebWeld	C'	496 +	0.00	-422.82	FAT-I	36.75	22.83*	0.00	3.42	44.00	12.00	12.00	3.42	3.51	PASS
BrgStiffWebWeld	C'	496 +	0.00	-422.82	FAT-I	2.25	-20.54*	0.00	-4.33***	---	---	---	---	---	---

Figure 29

Speck check at Stage 3->Built-up Alt->Span 1 90 ft. (left)

This shows the fatigue analysis of cover plate side weld to the top flange (fatigue category from specification).

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	Stress DL (ksi)	Stress +LL (ksi)	Stress -LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
CovPlFlgSideWeld	B	573 +	0.00	-425.18	FAT-I	38.50	25.62*	0.00	3.83	120.00	16.00	16.00	3.83	4.17	PASS

Figure 30

Speck check at Stage 3->Built-up Alt->Span 2 27 ft. (left)

This shows the fatigue analysis of cover plate end weld to the top flange (fatigue category from specification).

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	Stress DL (ksi)	Stress +LL (ksi)	Stress -LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
CovPlFlgEndWeld	E'	6485	211.36	-148.39	FAT-II	38.50	-0.47	-0.23	1.34	3.90	2.60	2.03	1.57	1.29	PASS

Figure 31

Speck check at Stage 3->Built-up Alt->Span 1 10 ft. (right).

This shows the fatigue analysis of the start of the longitudinal stiffener (fatigue category from specification).

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	Stress DL (ksi)	Stress +LL (ksi)	Stress -LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
LongStiffWebWeld	E	3530	152.43	-22.73	FAT-II	16.88	1.27	1.17	-0.17	11.00	4.50	2.87	1.34	2.14	PASS

Figure 32

Speck check at Stage 3->Built-up Alt->Span 1 60 ft. (left).

This shows the fatigue analysis of the end of the longitudinal stiffener (fatigue category from specification).

Detail	Cat.	ADTT(SL) 75 year T6.6.1.2.3-2	Max M LL+I (kip-in)	Min M LL+I (kip-in)	Limit State	Dist from Bottom (in)	-------- Stress --------- DL (ksi)	+LL (ksi)	-LL (ksi)	A*10^8 ((ksi^-3))	(F)TH (ksi)	(F)n (ksi)	f (ksi)	Fn/f	Code
LongStiffWebWeld	E	3530	229.36	-139.75	FAT-II	16.88	0.62	1.76	-1.07	11.00	4.50	2.87	2.83	1.01	PASS

Figure 33