

AASHTOWare BrDR 7.5.0

Culvert Tutorial

CVT3 – Metal Box Culvert Example

CVT3 – Metal Box Culvert Example

Topics Covered

- Metal Box Culvert Alternative
- LFR Rating
- LRFR Rating
- MBE 3rd edition, 2022 interims

Overview of Metal Box Culvert features

- Metal box culverts implemented in BrDR version 7.3.0 in October 2022
- Metal box culverts support LFR and LRFR rating methods
- Metal box culverts can be rated for plastic moment
- Single and multilane loading options available

Metal Box Culvert Alternative

From the **Bridge Explorer** create a **new bridge** and enter the following description data.

The screenshot shows the 'New Bridge' dialog box with the following details:

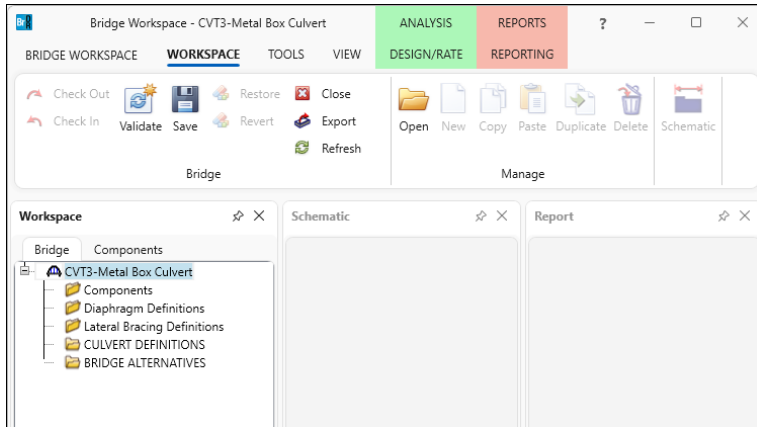
- Bridge ID:** CVT3-Metal Box Culvert
- NBI structure ID (8):** CVT3-Metal Box Culvert
- Template:**
- Bridge completely defined:**
- Bridge Workspace View:**
 - Superstructures
 - Culverts
 - Substructures
- Description Tab:**
 - Name:** CVT3-Metal Box Culvert Example
 - Year built:** [Empty]
 - Description:** Example of metal box culvert structure
 - Location:** [Empty]
 - Length:** [Empty] ft
 - Facility carried (7):** [Empty]
 - Route number:** 1
 - Feat. intersected (6):** [Empty]
 - Mi. post:** [Empty]
 - Default units:** US Customary
- Bridge association:** [Dropdown]
- BrR:** **BrD:** **BrM:**
- Buttons:** OK, Apply, Cancel

The **Superstructures** and **Culverts** checkboxes specify the types of structures the bridge contains. These checkboxes filter what to display in the **Bridge Workspace** tree. Since this bridge will only contain the metal box culvert, we only need to select culvert from the structure type check boxes.

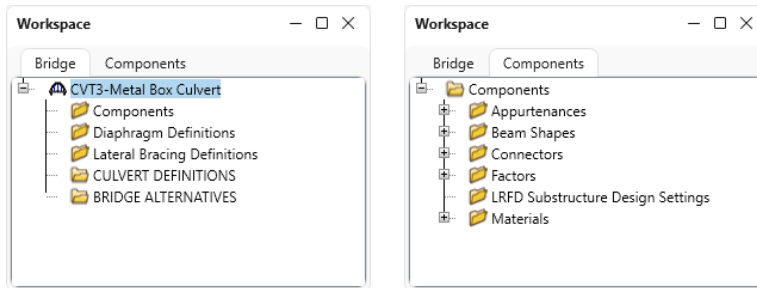
Close the window by clicking **OK**.

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To save the data to the database, click the **Save** button on the **Bridge** group of the **WORKSPACE** ribbon.



The **Bridge Workspace** tree and **Components** tree after the bridge is created is shown below.

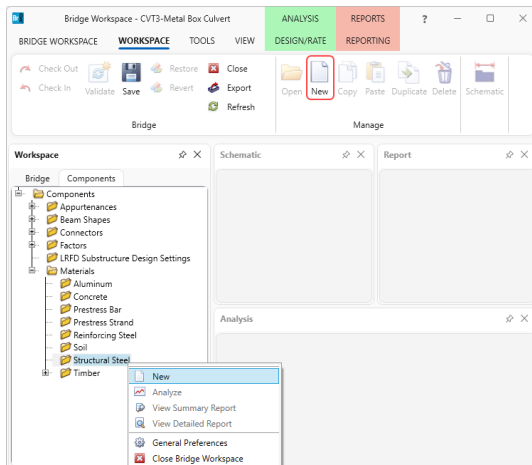


The **Bridge** tree is organized according to the definition of a bridge with data shared by many of the bridge components shown in the Components tab. A bridge can be described by working from top to bottom within the tree.

Bridge Materials

To enter the materials for the culvert, in the **Components** tab, expand the tree for **Materials**.

To add a structural steel material, double-click on the **Structural Steel** folder (or select **Structural Steel** and click on the **New** button from the **Manage** group of the **WORKSPACE** ribbon or right click and select **New**) to create a new structural steel material as shown below.



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Click on the **Copy from library...** button and copy the **Steel-Corrugated** structural steel to be used in the bridge as shown below.

Name	Description	Library	Units	F
Grade 30	AASHTO M270 Grade 30	Standard	US Customary	30.00
Grade 50W	AASHTO M270 Grade 50W	Standard	US Customary	50.00
Grade 690 - > 65 to 100 incl.	AASHTO M270M - over 65 to 100 mm thick, inclusive	Standard	SI / Metric	
Grade 690 <= 65 mm	AASHTO M270M Grade 690 up to 65 mm thick, inclusive	Standard	SI / Metric	
Grade 690W - > 65 to 100 incl.	AASHTO M270M - over 65 to 100 mm thick, inclusive	Standard	SI / Metric	
Grade 690W <= 65 mm	AASHTO M270M Grade 690W up to 65 mm thick, inclusive	Standard	SI / Metric	
Grade 70W - Fu = 85 ksi	AASHTO M270 Grade 70W - Fu = 85 ksi	Standard	US Customary	70.00
Grade 70W - Fu = 90 ksi	AASHTO M270 Grade 70W - Fu = 90 ksi	Standard	US Customary	70.00
Prior to 1905	Built prior to 1905 - steel unknown	Standard	US Customary	26.00
> Steel - Corrugated	Structural plate (thickness 0.176"-0.250")	Standard	US Customary	

The **Bridge Materials – Structural Steel** window will be updated with material information as shown below.

Name:

Description:

Material properties

Specified minimum yield strength (Fy): ksi

Specified minimum tensile strength (Fu): ksi

Coefficient of thermal expansion: 1/F

Density: kcf

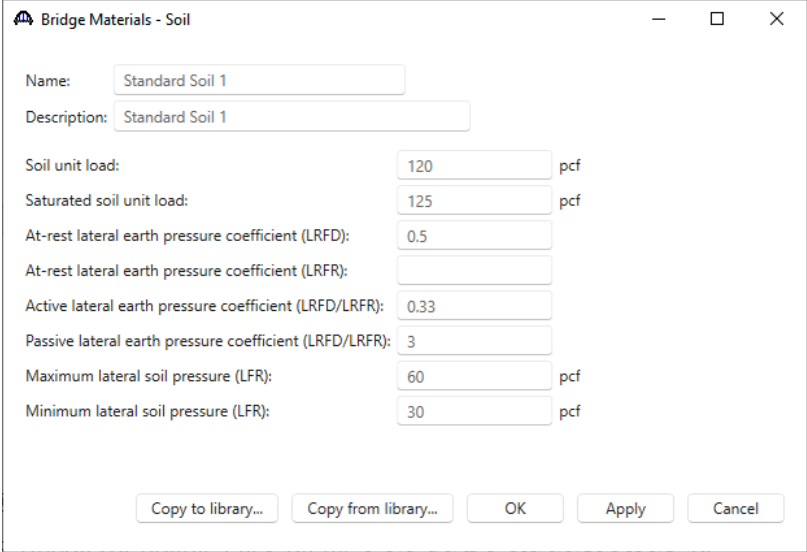
Modulus of elasticity (E): ksi

Click **OK** to add the new structural steel material and close the window.

Similarly add a new soil material by double-clicking on the **Soil** folder or selecting **Soil** and clicking on **New** on the **Manage** group of the **WORKSPACE** ribbon or right clicking on **Soil** and selecting **New** from the menu. Click on the **Copy from library...** button to copy the **Standard Soil 1** material to the bridge.

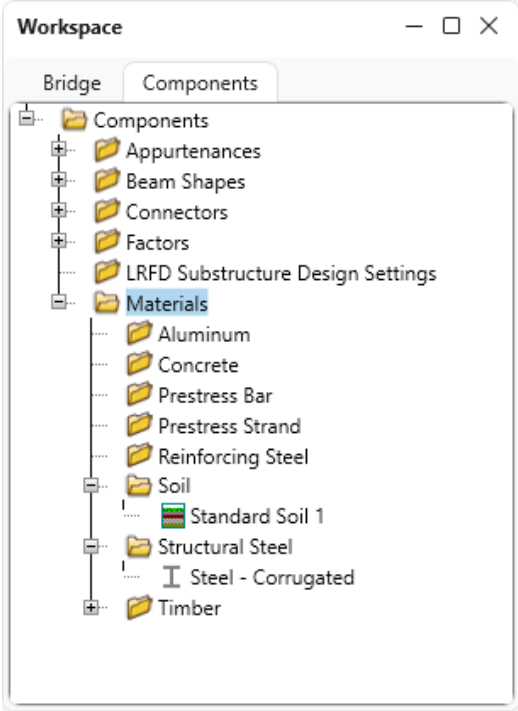
Name	Description	Library	Units	Soil unit load	At-rest lateral earth pressure coefficient (LRFD/LRF)	Maximum lateral soil pressure (LFR)
> Standard Soil 1	Standard Soil 1	Standard	US Customary	120	0.5	60
Standard Soil 2	Standard Soil 2	Standard	US Customary	120	0.5	30

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Click **OK** to add the soil material and close the window.

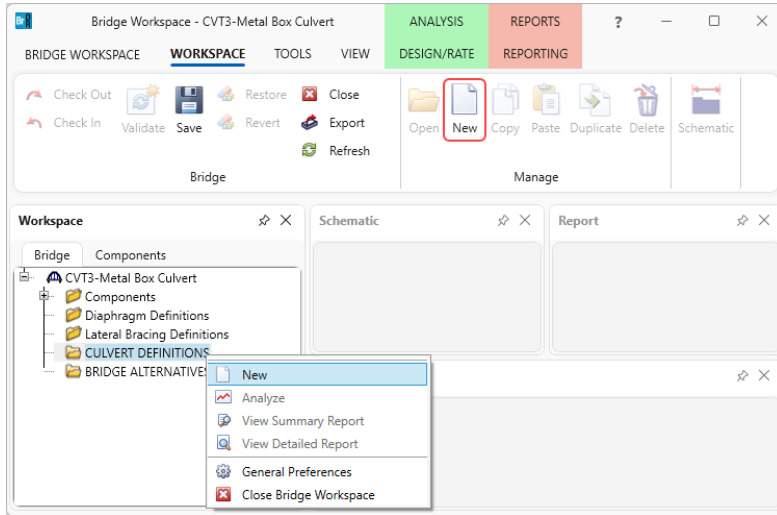
The **Components** tree with the materials to be used by the culvert is shown below.



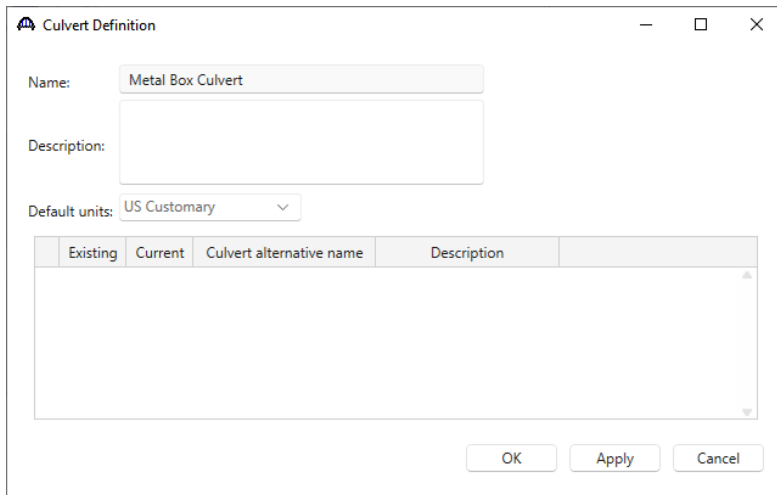
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Culvert Definition

To create a new culvert definition, navigate to the **Bridge** tab of the **Bridge Workspace** tree and click on **CULVERT DEFINITIONS** in the **Bridge Workspace** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or double click on the **CULVERT DEFINITION**, or right click and select **New**).



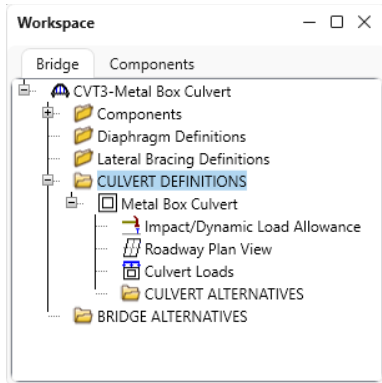
Enter the Culvert Definition **Name** as shown below. The first Culvert Alternative added will automatically be assigned as the **Existing** and **Current** Culvert Alternative for this Culvert Definition.



Click **OK** to apply the data and close the window.

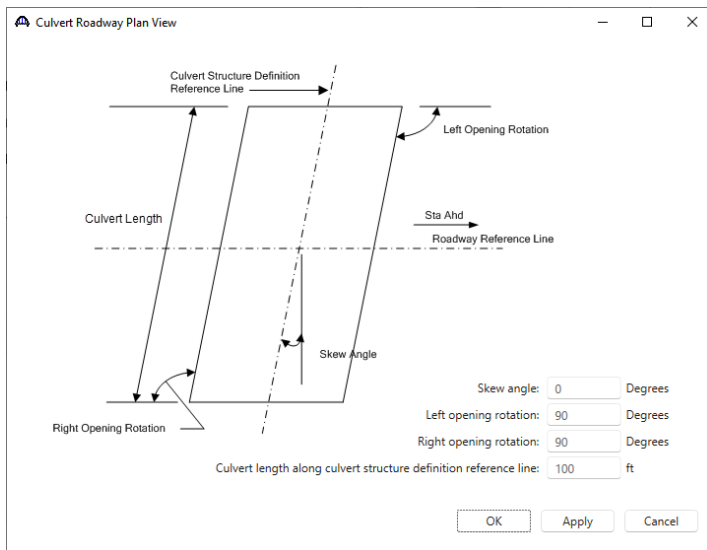
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Expand the tree for the new culvert structure definition as shown below.



Culvert Roadway Plan View

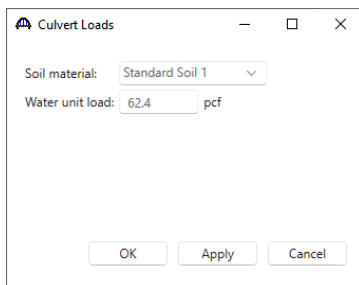
Double click on the **Roadway Plan View** node in the **Bridge Workspace** tree to open the **Culvert Roadway Plan View** window. Enter the culvert orientation details as shown below.



Click **OK** to apply the data and close the window.

Culvert Loads

Double-click on the **Culvert Loads** node to open the **Culvert Loads** window. Select the Soil material from the drop-down menu. Water unit load will be populated by default as 62.40 pcf.

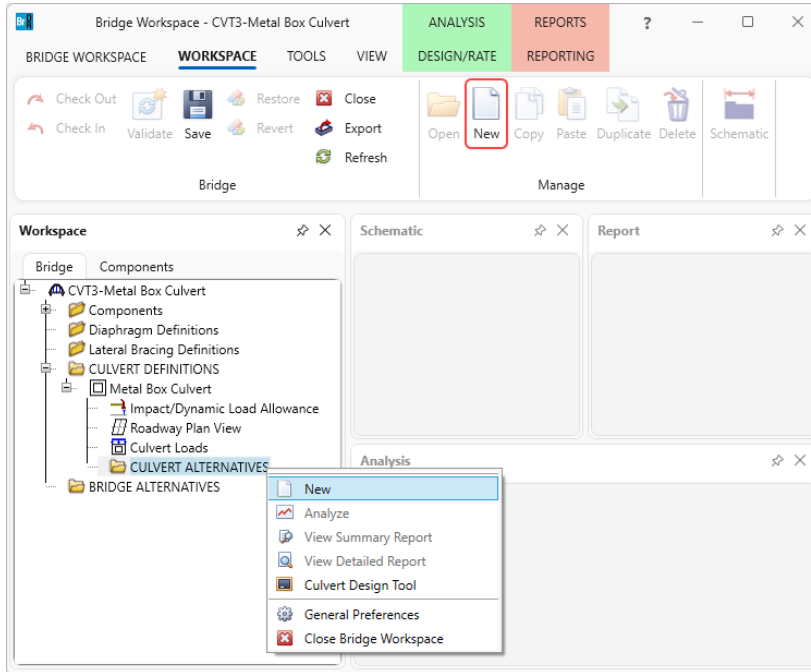


Click **OK** to apply the data and close the window.

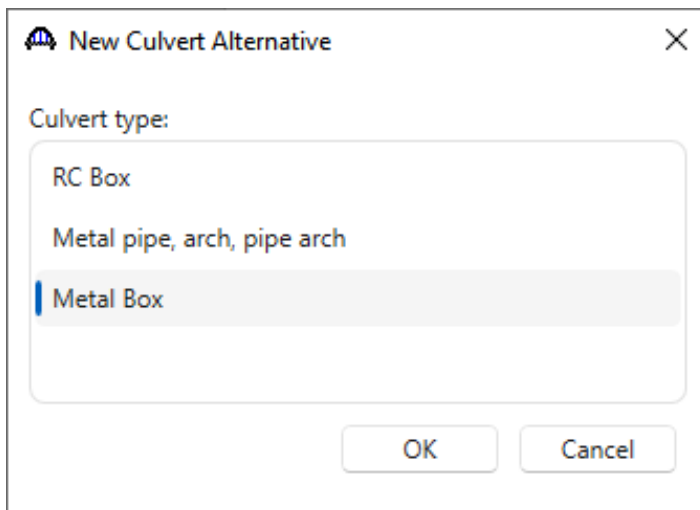
CVT3 – Metal Box Culvert Example

Culvert Alternative

To create a new culvert alternative, click on **CULVERT ALTERNATIVES** in the **Bridge Workspace** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or double click on the **CULVERT ALTERNATIVES**, or right click and select **New**).



Select **Metal Box** in the **New Culvert Alternative** window and click **OK** to open the **Culvert Alternative Description** window as shown below.



CVT3 – Metal Box Culvert Example

Enter the culvert alternative description as shown below.

Culvert Alternative Description

Culvert alternatives: 20ft Metal Box Culvert

Description Specs Factors Control options

Description:

Culvert type: Metal box culvert

Default units: US Customary

Default rating method: LRFR

OK Apply Cancel

Select the **Specs** tab. AASHTO Metal Culvert Engine is selected as the analysis module for both LFR and LRFR analysis.

Culvert Alternative Description

Culvert alternatives: 20ft Metal Box Culvert

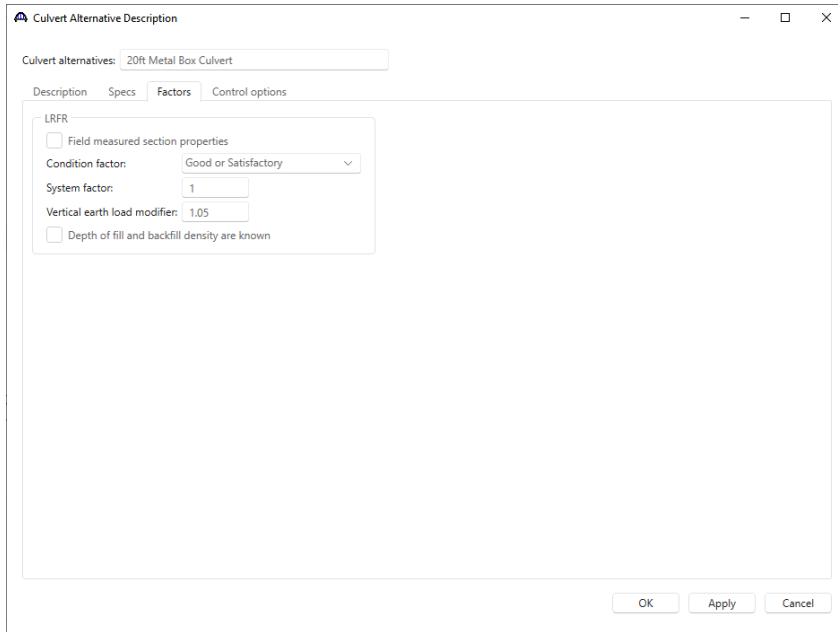
Description Specs Factors Control options

Analysis method type	Analysis module	Selection type	Spec version	Factors
LFR	AASHTO Metal Culvert LFR	System Default	MBE 3rd 2023i, Std 17th	2002 AASHTO Std. Specifications
LRFR	AASHTO Metal Culvert LRFR	System Default	MBE 3rd 2023i, LRFD 9th	2018 (2022 Interim) AASHTO LRFR Spec.

OK Apply Cancel

CVT3 – Metal Box Culvert Example

Select the **Factors** tab and enter the factors for **LRFR** as shown below.



The screenshot shows the 'Culvert Alternative Description' dialog box with the 'Factors' tab selected. The 'Culvert alternatives' field contains '20ft Metal Box Culvert'. The 'LRFR' section includes the following options:

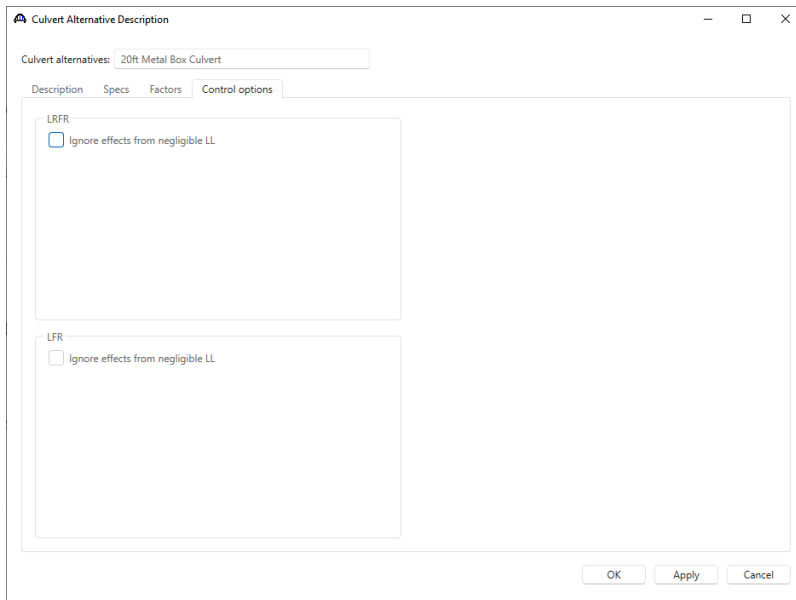
- Field measured section properties
- Condition factor: Good or Satisfactory (dropdown menu)
- System factor: 1 (text input)
- Vertical earth load modifier: 1.05 (text input)
- Depth of fill and backfill density are known

Buttons for 'OK', 'Apply', and 'Cancel' are located at the bottom right of the dialog.

The **Control options** tab has advanced analysis options for LFR and LRFR analysis methods. By default, none of the options are selected.

Description of Metal Box Culvert Alternative control options:

- Ignore effects from negligible live load – Use this control option to skip the rating when factored live load pressure at the depth of the culvert is less than 10% of the total factored pressure at the depth of the culvert.



The screenshot shows the 'Culvert Alternative Description' dialog box with the 'Control options' tab selected. The 'Culvert alternatives' field contains '20ft Metal Box Culvert'. The 'LRFR' section includes the following options:

- Ignore effects from negligible LL

The 'LFR' section also includes the following options:

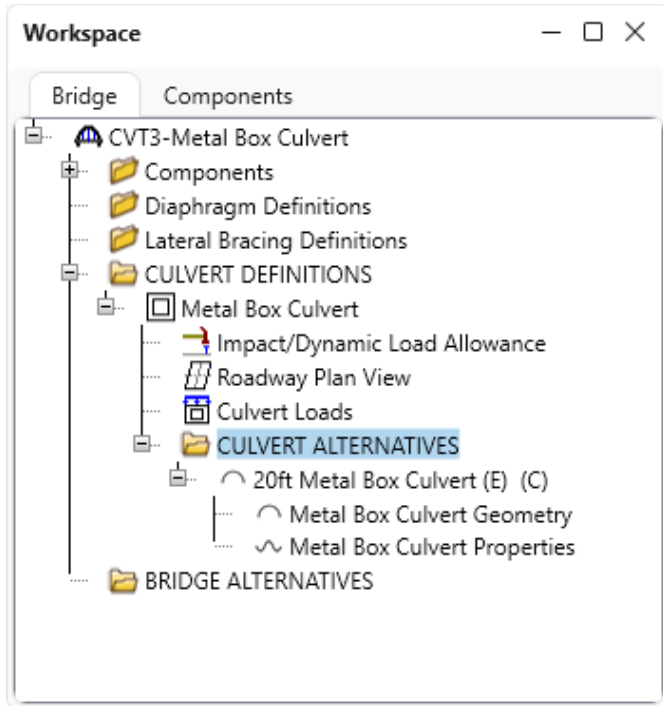
- Ignore effects from negligible LL

Buttons for 'OK', 'Apply', and 'Cancel' are located at the bottom right of the dialog.

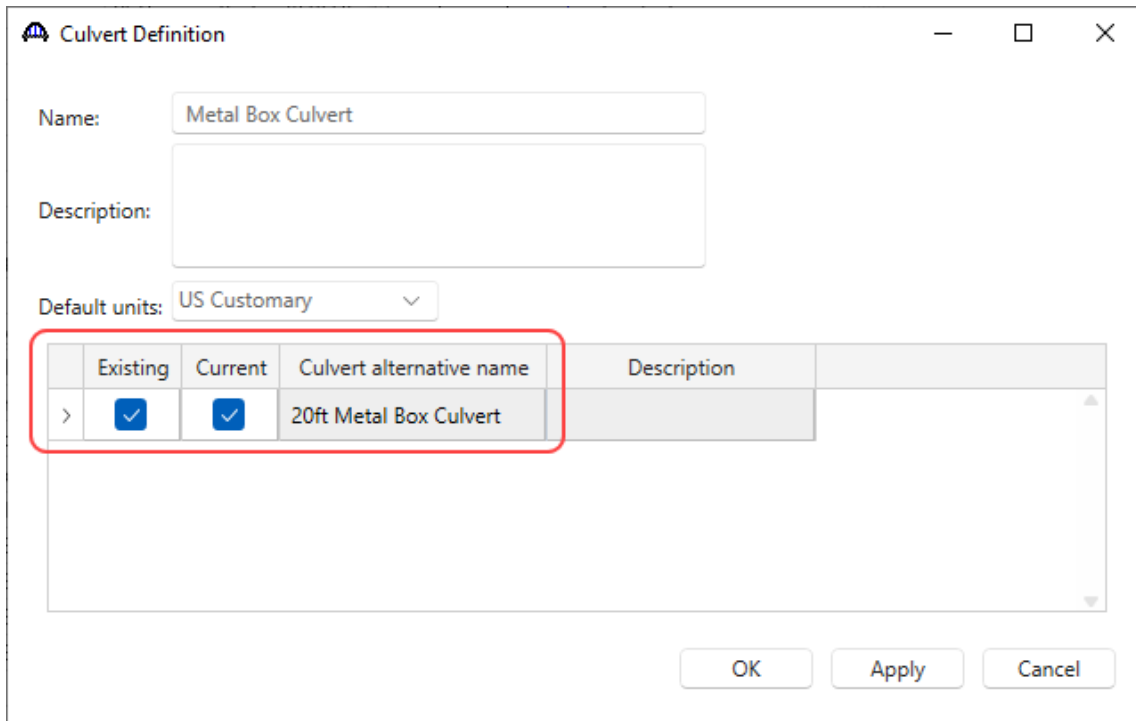
Click Ok to apply the data and close the window.

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Expand the tree for the new culvert alternative as shown below.



Note that the **20ft Metal Box Culvert** is automatically assigned as the **Existing** and **Current** alternative shown by the **(E)** and **(C)** in the name. This culvert alternative is also updated as **Existing** and **Current** alternative in the **Culvert Definition** window as shown below.

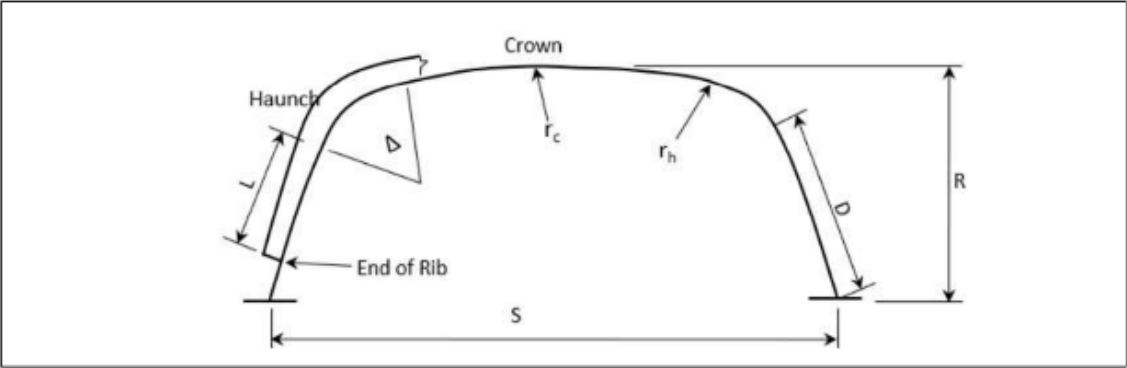


CVT3 – Metal Box Culvert Example

Metal Box Culvert Geometry

Double click on the **Metal Box Culvert Geometry** node in the **Bridge Workspace** tree to open the **Metal Box Culvert Geometry** window to enter the culvert geometry. Enter the data as shown below.

Metal Box Culvert Geometry [-] [□] [×]



Span (S): ft Delta: Degrees
Rise (R): ft D: ft
rc: ft L: ft
rh: ft Height of cover (H): ft
Pavement reduction factor: %

Comment:

Click **OK** to apply the data and close the window.

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Metal Box Culvert Properties

Double-click on the **Metal Box Culvert Properties** node in the **Bridge Workspace** tree to enter the box culvert section properties, material, and culvert condition. Both steel and aluminum materials are available for the metal box culverts. First, select the Material type as **Steel** and select **Steel - Corrugated** from its drop down menu.

Metal Box Culvert Properties

Material type: Steel Aluminum

Material: Steel - Corrugated

Section properties

Copy from library

Name:

Mp crown: kip-ft/ft

Mp haunch: kip-ft/ft

Condition

Mp crown adjustment factor: %

Mp haunch adjustment factor: %

OK Apply Cancel

For section properties, click on the **Copy from library** button and select **Stl 15" x 5 1/4" Corrugated Box No Rib** with shell thickness 0.250 and Mp 30.40 and click **OK**

Library Data: Metal Box Culvert - Steel Metal Box

Name	Units	Rib Thickness	Rib Spacing	Shell thickness	Mp
> Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.25	30.4
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.111	
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.15	10.8
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.175	13.2
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.225	25.3
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.225	17.3
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.25	19.8
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.2	22.3
Stl 15" x 5 1/4" Corrugated Pipe No Rib	US Customary			0.2	14.8
Stl 6"x2" Corrugated Plate Angle Rib	US Customary		18"	0.15	18.8

OK Apply Cancel

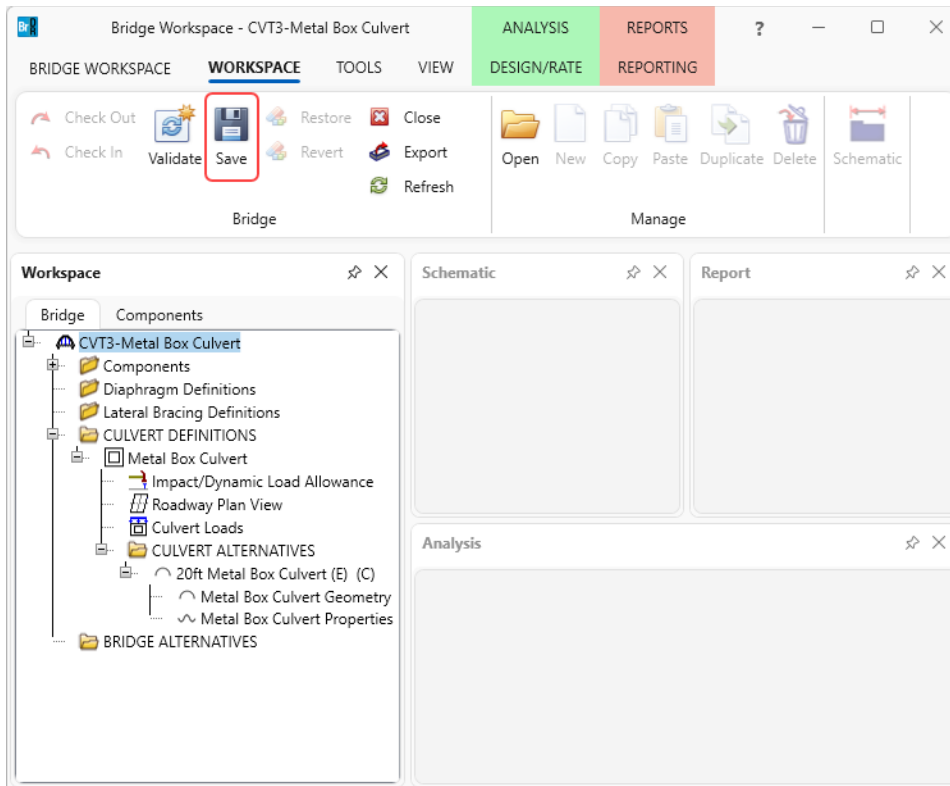
CVT3 – Metal Box Culvert Example

Enter the data for **Condition** as shown below and click **OK** to save the data to memory and close the window.

The screenshot shows the 'Metal Box Culvert Properties' dialog box. It has a title bar with a close button. The 'Material type' section has radio buttons for 'Steel' (selected) and 'Aluminum'. The 'Material' dropdown menu is set to 'Steel - Corrugated'. The 'Section properties' section includes a 'Copy from library' button, a 'Name' field containing 'Stl 15" x 5 1/4" Corrugated Pipe No Rib', and two input fields: 'Mp crown' with the value '30.4' and 'kip-ft/ft', and 'Mp haunch' with the value '30.4' and 'kip-ft/ft'. The 'Condition' section has two input fields: 'Mp crown adjustment factor' with the value '100' and '%', and 'Mp haunch adjustment factor' with the value '100' and '%'. At the bottom right, there are three buttons: 'OK', 'Apply', and 'Cancel'.

Click **OK** to apply the data and close the window.

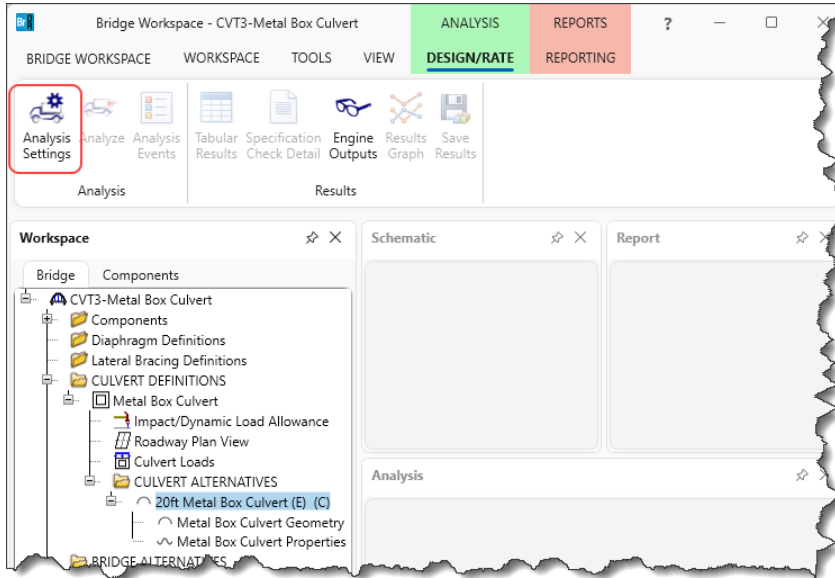
The description of the metal box culvert is complete. To save the new culvert to the database, click the **Save** button on **WORKSPACE** ribbon.



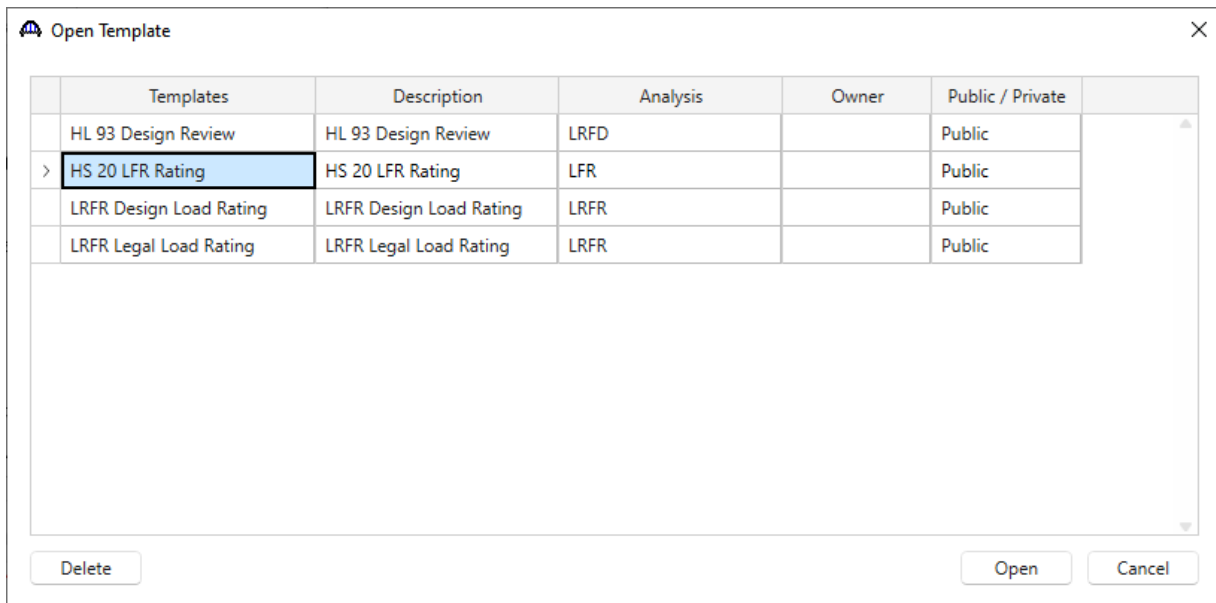
CVT3 – Metal Box Culvert Example

LFR Rating

To perform an LFR Rating, select the **20ft Metal Box Culvert** alternative in the **Bridge Workspace** tree and click the **Analysis Settings** button from the **Analysis** group of the **DESIGN/RATE** ribbon.



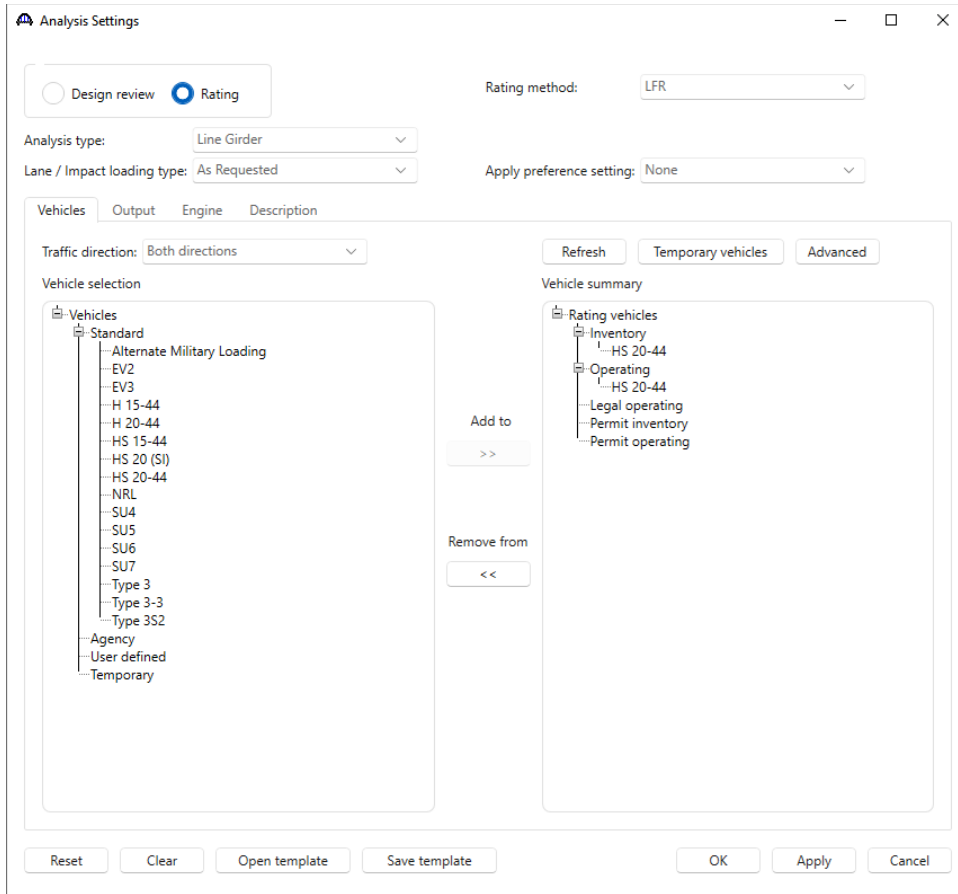
The **Analysis Settings** window will open. Click the **Open template** button and select the **HS 20 LFR Rating** to be used in the rating and click Open.



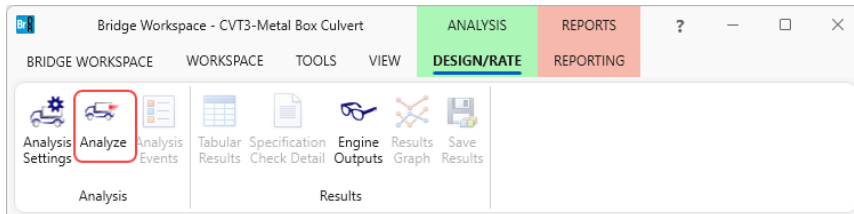
Click **OK** to apply the data and close the window.

CVT3 – Metal Box Culvert Example

The **Analysis Settings** window will be populated as shown below. Click **OK** to apply the data and close the window.

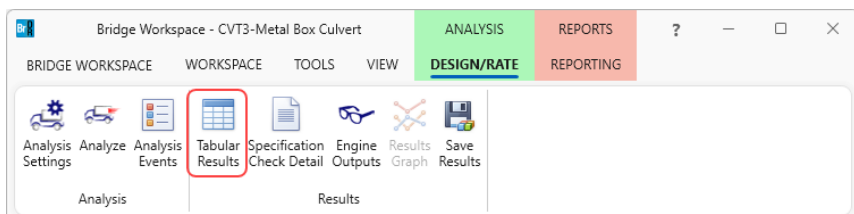


Click the **Analyze** button from the **Analysis** group of the **DESIGN/RATE** ribbon to start the rating process.



Tabular Results

When the rating is finished, results can be reviewed by clicking the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon.



CVT3 – Metal Box Culvert Example

The window shown below will open. Select **Single rating level per row** as the display format to display the output in single rows as shown below.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Limit State	Impact	Lane
HS 20-44	Axle Load	LFR	Inventory	64.36	1.788	Plastic Moment	As Requested	As Requested
HS 20-44	Axle Load	LFR	Operating	107.47	2.985	Plastic Moment	As Requested	As Requested

Specification Check Detail

To review detailed rating results at the controlling location, the **Specification Check Detail** button in the ribbon to open the **Specification** window.

Specification reference	Limit State	Flex. Sense	Pass/Fail
12.8.4.3 Plastic Moment Requirements		N/A	General Comp.
12.8.4.3.C Plastic Moment Requirements - C Factors		N/A	General Comp.
12.8.4.3.DL Plastic Moment Requirements - Dead Load		N/A	General Comp.
12.8.4.3.K Plastic Moment Requirements - K Factors		N/A	General Comp.
12.8.4.3.LL Plastic Moment Requirements - Live Load		N/A	General Comp.
3.8.2.3 Culvert Impact Factor		N/A	General Comp.
✓ 6B.4.1 Metal Plate Box Culvert Rating - Plastic Moment		N/A	Passed

CVT3 – Metal Box Culvert Example

Double click on the **6B.4.1 Metal Plate Box Culvert Rating – Plastic Moment** specification article to open the Spec Check Detail window.

Part B - ALLOWABLE STRESS RATING AND LOAD FACTOR RATING
6B.4 RATING EQUATION
6B.4.1 General Plastic Moment
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

Metal Culvert - 20ft Metal Box Culvert - Center Stage 3

Input:

Ignore negligible live load: No
Resistance Factor (phi) = 1.00
Crown Plastic Moment Capacity (MpC) = 30.40
Haunch Plastic Moment Capacity (MpH) = 30.40

Plastic Moment Capacity

$$RF = \frac{\phi * M_p - A_{ev} * M_E}{A_2 * M_{LL+IM}} \quad (6B.4.1)$$

Load	Load Combo	M_E (kip-ft/ft)	Crown M_LL+IM (kip-ft/ft)	Mp (kip-ft/ft)	M_E (kip-ft/ft)	Haunch M_LL+IM (kip-ft/ft)	Mp (kip-ft/ft)	Load Factors Aev	A2	Crown RF	Haunch RF	RF	Capacity (kip)
Inventory	1	3.50	6.07	30.40	3.81	5.76	30.40	1.95	2.17	1.788	1.836	1.788	128.71
Operating	1	3.50	6.07	30.40	3.81	5.76	30.40	1.95	1.30	2.985	3.067	2.985	214.95

Load Combination Legend:

Code	Vehicle
1	HS 20-44 - Truck

OK

LRFR Analysis

Close the spec check window and reopen the **Analysis Settings** window to test a **LRFR** analysis. Enter the analysis settings as shown below.

Analysis Settings

Design review Rating

Rating method: LRFR

Analysis type: Line Girder

Lane / Impact loading type: As Requested

Apply preference setting: None

Traffic direction: Both directions

Refresh Temporary vehicles Advanced

Vehicle selection

- Standard
 - EV2
 - EV3
 - H 15-44
 - H 20-44
 - HL-93 (S)
 - HL-93 (US)**
 - HS 15-44
 - HS 20 (S)
 - HS 20-44
 - Lane-Type Legal Load
 - LRFD Fatigue Truck (S)
 - LRFD Fatigue Truck (US)
 - NRL
 - SU4
 - SU5
 - SU6
 - SU7
 - Type 3
 - Type 3-3
 - Type 352
 - Agency
 - User defined
 - Temporary

Add to >>

Remove from <<

Vehicle summary

- Rating vehicles
 - LRFR
 - Design load rating
 - Inventory
 - HL-93 (US)
 - Operating
 - HL-93 (US)
 - Fatigue
 - Legal load rating
 - Routine
 - Specialized hauling
 - Permit load rating

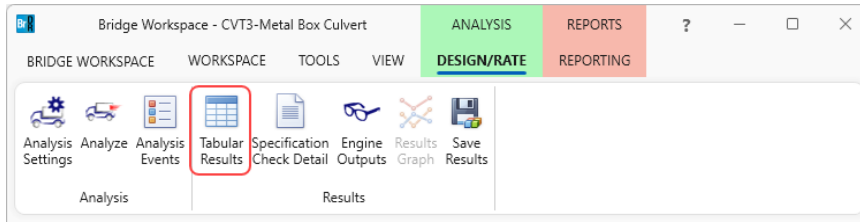
Reset Clear Open template Save template OK Apply Cancel

Click **OK** to apply the settings and close the window.

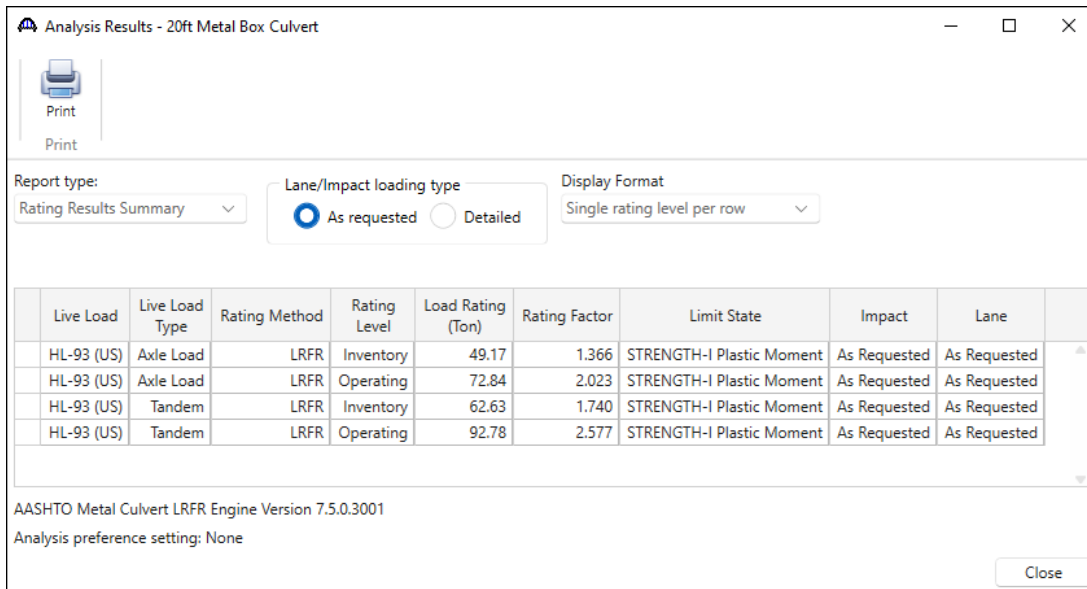
CVT3 – Metal Box Culvert Example

Tabular Results

Click **Analyze** on the ribbon to launch the rating. When the rating is complete, review the results by clicking the **Tabular Results** button on the ribbon.

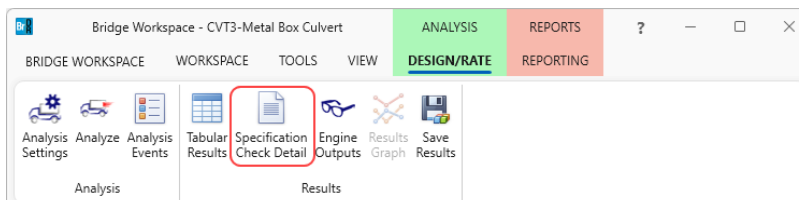


The window shown below will open. Select **Single rating level per row** as the display format to display the output in single rows as shown below.



Specification Check Detail

To review detailed rating results at the controlling location, the **Specification Check Detail** button in the ribbon to open the **Specification** window.



CVT3 – Metal Box Culvert Example

Double-click on the **6A.10.4 Culvert Load Rating Equation – Plastic Moment** specification article to open the Spec Check Detail window.

Specification Checks for 20ft Metal Box Culvert - 8 of 8

Articles: All articles (dropdown)
 Format: Bullet list (dropdown)

Specification filter: **Culvert Component** > **Stage 3** > **20ft Metal Box Culvert** > **20ft Metal Box Culvert**

Specification reference	Limit State	Flex. Sense	Pass/Fail
12.9.4.2.C Moments due to Factored Loads - C Factors		N/A	General Comp.
12.9.4.2.DL Moments due to Factored Loads - Dead Load		N/A	General Comp.
12.9.4.2.K Moments due to Factored Loads - K Factors		N/A	General Comp.
12.9.4.2.LL Moments due to Factored Loads - Live Load		N/A	General Comp.
12.9.4.3 Plastic Moment Resistance		N/A	General Comp.
12.9.4.4 Crown Soil Cover Factor		N/A	General Comp.
3.6.2.2 Culvert Dynamic Load Allowance		N/A	General Comp.
✓ 6A.10.4 Culvert Load Rating Equation - Plastic Moment		N/A	Passed

Spec Check Detail for 6A.10.4 Culvert Load Rating Equation - Plastic Moment

Part A - LOAD AND RESISTANCE FACTOR RATING
 6A.10 Rating of Culverts
 6A.10.4 Load Rating Equation for Culverts
 Plastic Moment
 (AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

Metal Culvert - 20ft Metal Box Culvert - Center Stage 3

Input:

Ignore negligible live load: No
 Depth of fill and backfill density are known: No
 Condition Factor (phiC) = 1.00
 System Factor (phiS) = 1.00
 Resistance Factor (phi) = 1.00
 Vertical Earth Load Modifier (etaR) = 1.05
 Crown Plastic Moment Capacity (MpC) = 30.40
 Haunch Plastic Moment Capacity (MpH) = 30.40

Plastic Moment Capacity

$$RF = \frac{\phi_i C \cdot \phi_i S \cdot \phi_i \cdot M_p - \eta_a R \cdot \gamma_{EV} \cdot M_{E}}{\gamma_{LL+IM} \cdot M_{LL+IM}} \quad (6A.10.4-1)$$

Load	Load Combo	Limit State	M _E (kip-ft/ft)	Crown M _{LL+IM} (kip-ft/ft)	M _p (kip-ft/ft)	M _E (kip-ft/ft)	Haunch M _{LL+IM} (kip-ft/ft)	M _p (kip-ft/ft)	Load Factors EV LL	Crown RF	Haunch RF	RF	Capacity (kip)
DesignInv	1	STR-I	3.60	9.05	30.40	3.97	8.68	30.40	1.50 2.00	1.366	1.390	1.366	98.33
DesignInv	1	STR-I	3.60	9.05	30.40	3.97	8.68	30.40	0.90 2.00	1.491	1.534	1.491	107.36
DesignOp	1	STR-I	3.60	9.05	30.40	3.97	8.68	30.40	1.50 1.35	2.023	2.060	2.023	145.68
DesignOp	1	STR-I	3.60	9.05	30.40	3.97	8.68	30.40	0.90 1.35	2.209	2.273	2.209	159.05
DesignInv	2	STR-I	3.62	7.10	30.40	3.96	6.76	30.40	1.50 2.00	1.740	1.788	1.740	125.25
DesignInv	2	STR-I	3.62	7.10	30.40	3.96	6.76	30.40	0.90 2.00	1.900	1.972	1.900	136.81
DesignOp	2	STR-I	3.62	7.10	30.40	3.96	6.76	30.40	1.50 1.35	2.577	2.648	2.577	185.56
DesignOp	2	STR-I	3.62	7.10	30.40	3.96	6.76	30.40	0.90 1.35	2.815	2.922	2.815	202.68

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck
2	HL-93 (US) - Tandem

OK