AASHTOWare BrDR 7.5.0

Culvert Tutorial

CVT2 – Corrugated Metal Pipe Culvert Example

CVT2 – Corrugated Metal Pipe Culvert Example

Topics Covered

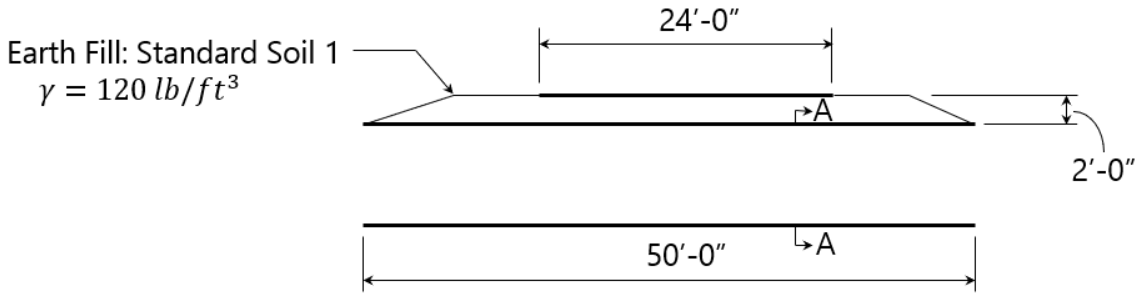
- Metal Pipe Culvert Alternatives
- LFR Rating
- LRFR Rating
- MBE 2022 approved ballot item specification updates

Overview of Metal Pipe Culvert features

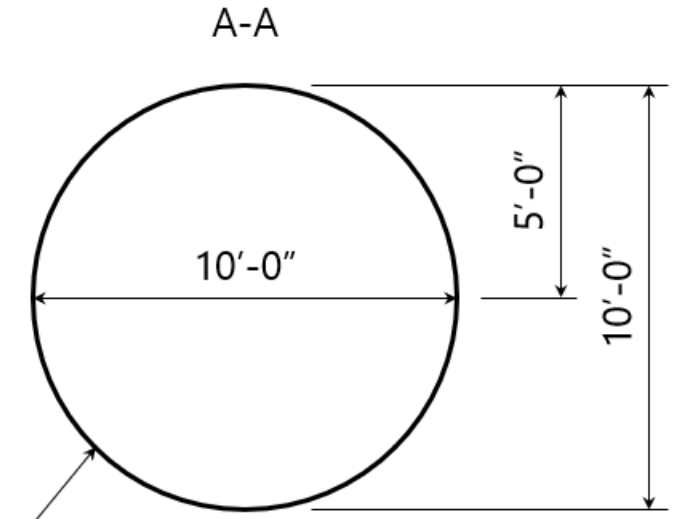
- Metal pipe culverts implemented in BrDR version 7.3.0 in September 2022
- Metal pipe culverts support LFR and LRFR rating methods
- Metal pipe culverts can be rated for wall capacity and plastic moment
- Single and multilane loading options available

This tutorial describes the data entry for a corrugated metal pipe culvert using the metal pipe culvert alternative in BrDR version 7.5.0.

Elevation



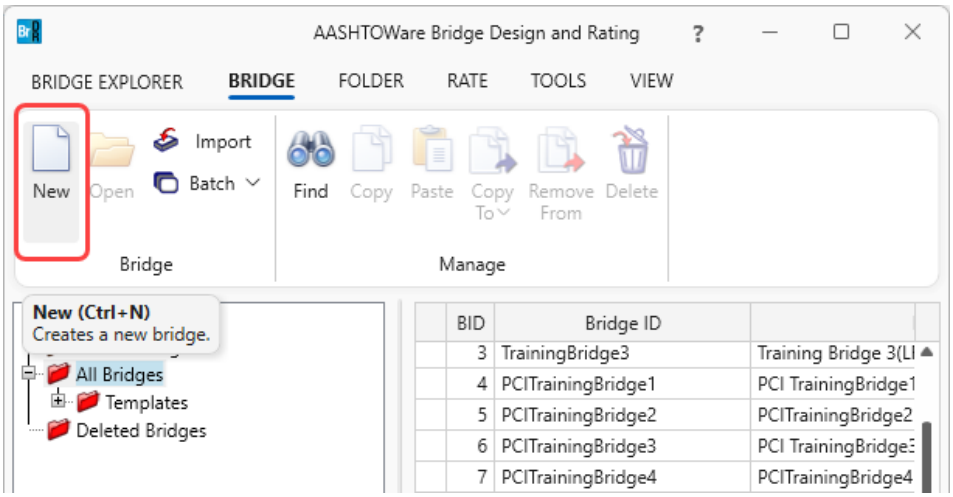
Cross Section

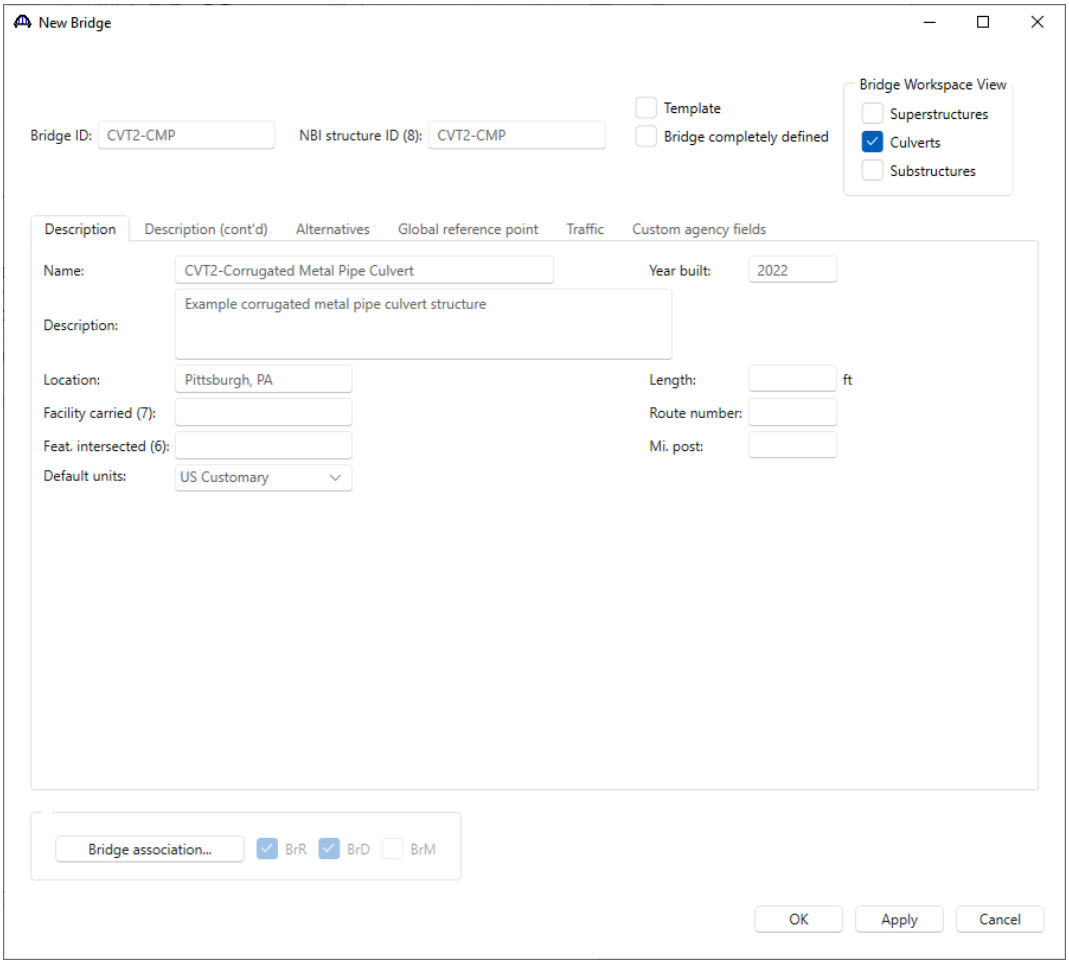


5 x 1 Corrugated stl. Pipe
$t = 0.109\ in$
$A = 1.390\ in^2/ft$
$r = 0.3677\ in$
$I = 15.650\ * 10^{-3}\ in^4/in$
$Mp = 2.660\ kip - ft/ft$
$Seam\ Strength = 62.0\ kip/ft$

Corrugated Metal Pipe Data Entry

From the **Bridge Explorer** create a new bridge by clicking on the **New** button in the **Bridge** group of the **BRIDGE** ribbon and enter the description data as shown below.

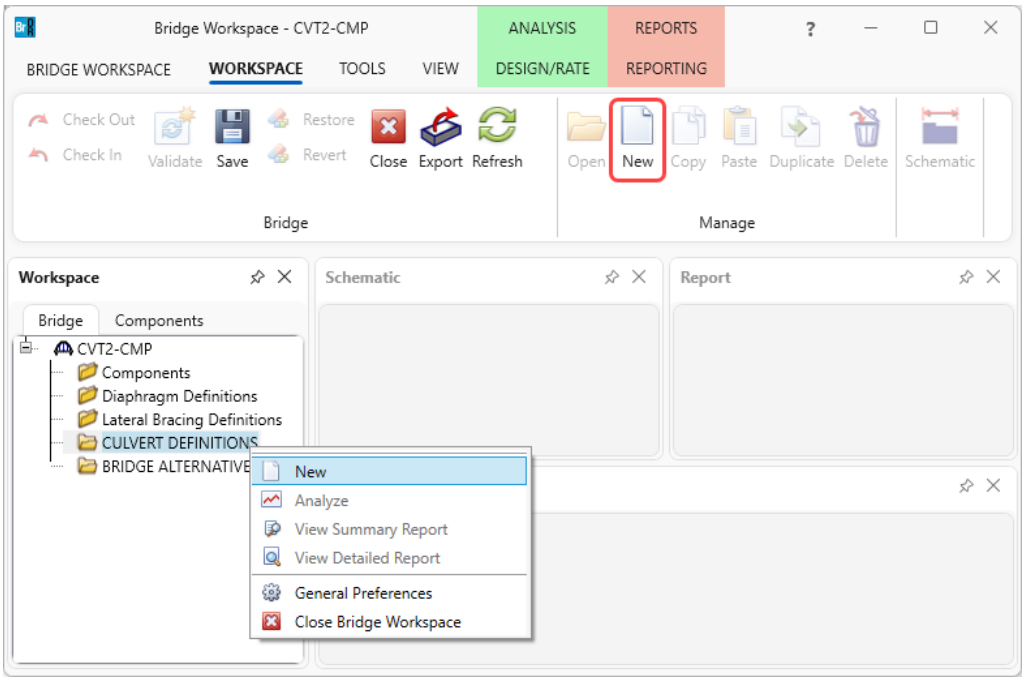


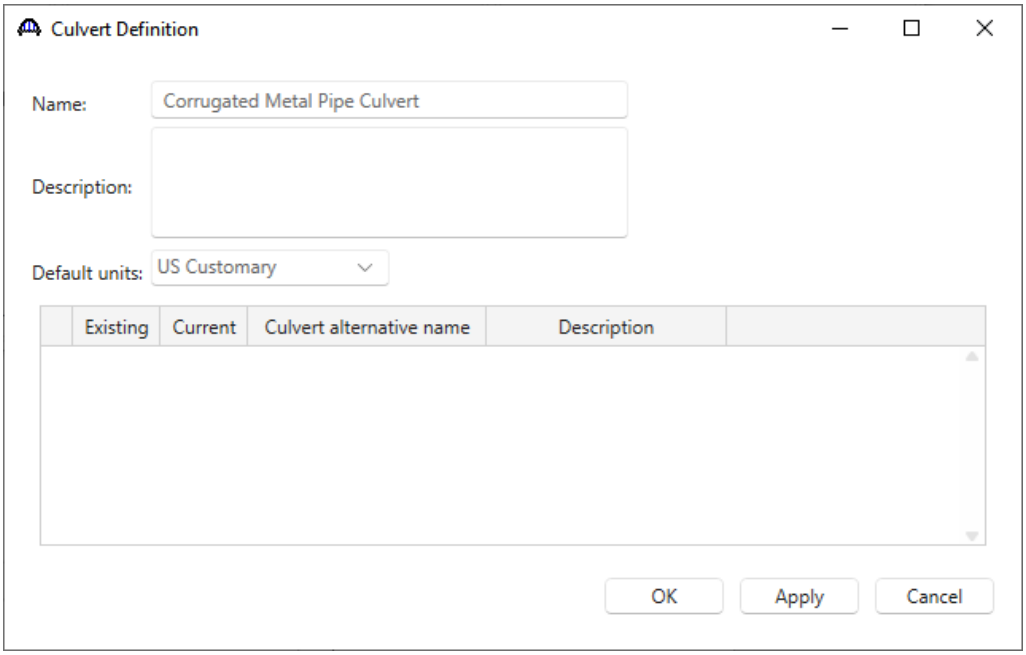


Close the window by clicking **OK**.

Culvert Definition

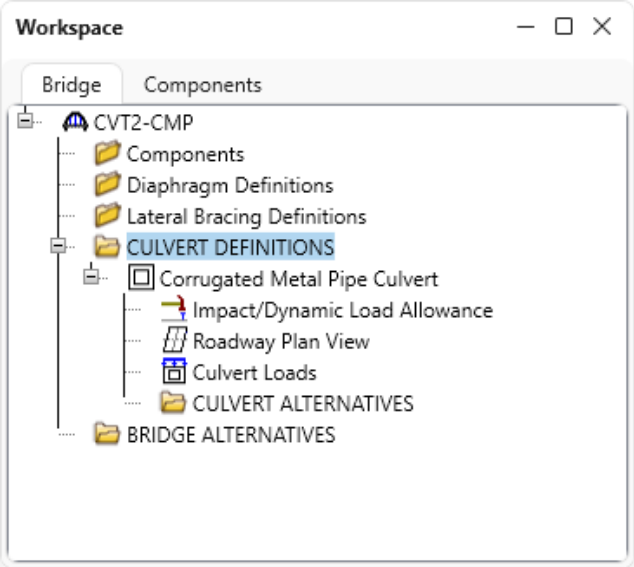
To create a new culvert definition, click on **CULVERT DEFINITIONS** in the **Bridge Workspace** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or double click on the **CULVERT DEFINITION,** or right click and select **New).** Enter the Culvert Definition **Name** as show below.





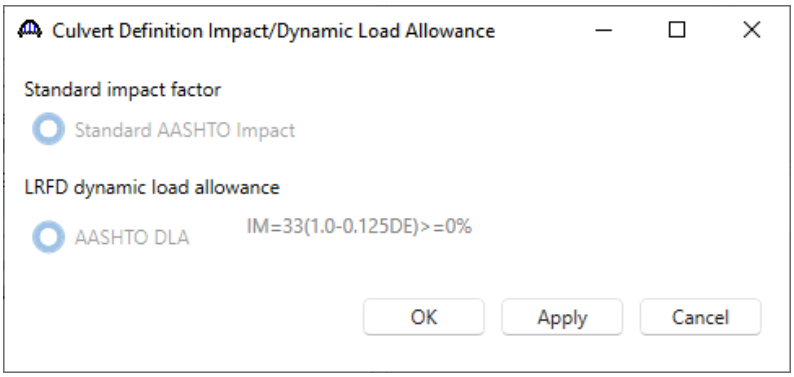
Click **OK** to apply the data and close the window.

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



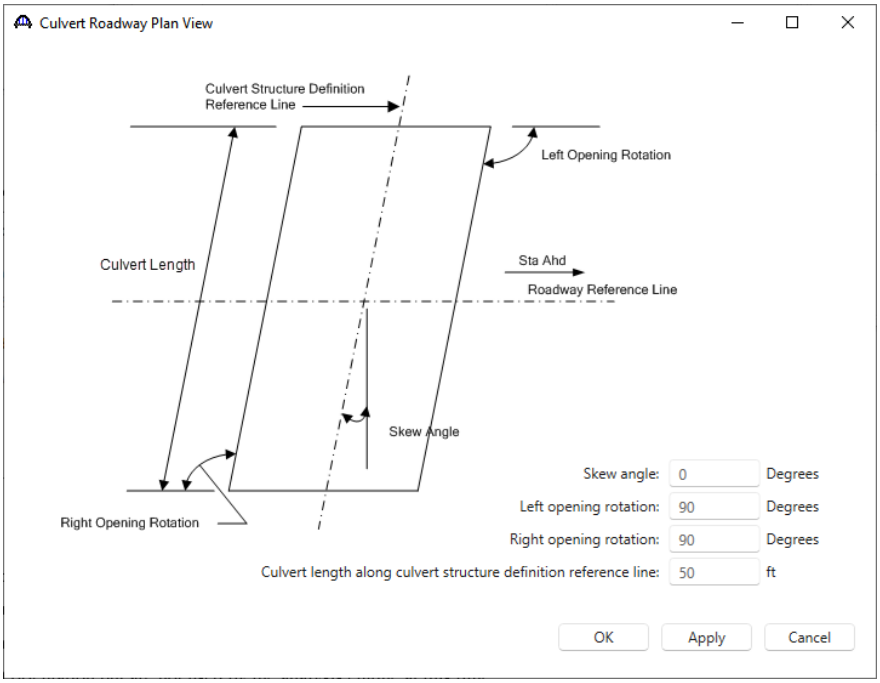
Impact/Dynamic Load Allowance

Impact (LFD) and Dynamic Load Allowance (LRFD) cannot be modified for culvert structure definition, therefore, no additional input can be entered on the **Culvert Definition Impact/Dynamic Load Allowance** window.



Culvert Roadway Plan View

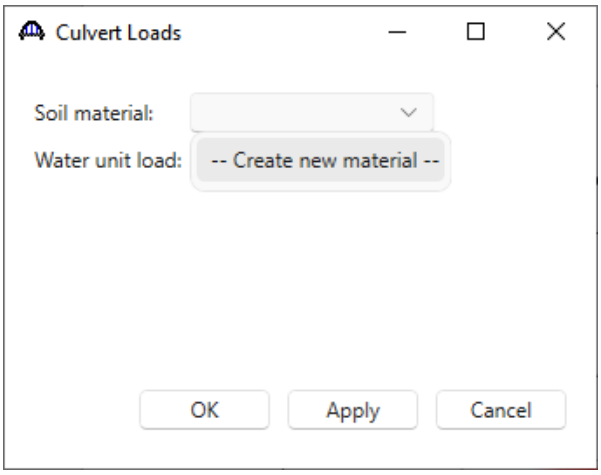
Double click on the **Roadway Plan View** node in the **Bridge Workspace** tree to open the **Culvert Roadway Plan View** window. Enter the culvert orientation details as shown below. The **Culvert length along culvert structure definition reference line** must be input for the live load pressure distribution calculations. The other input items help define the culvert orientation but are not used by the analysis engine at this time.



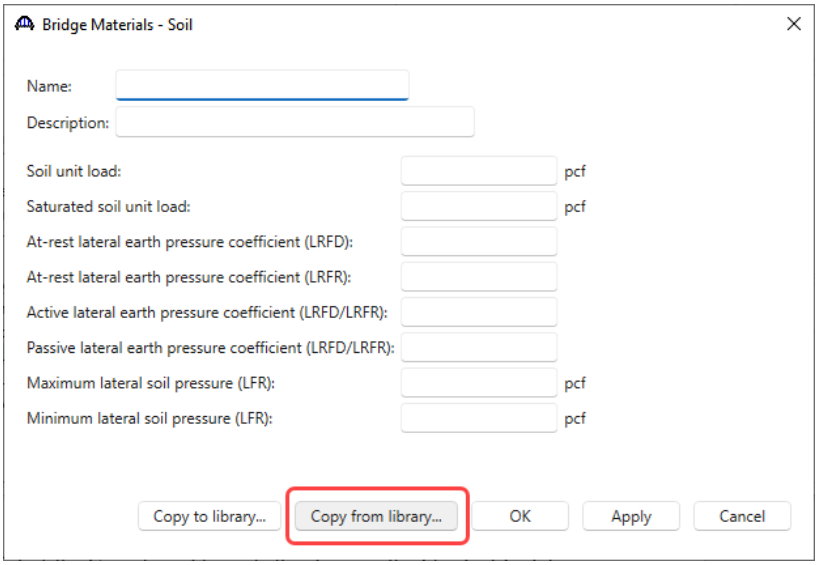
Click **OK** to apply the data and close the window.

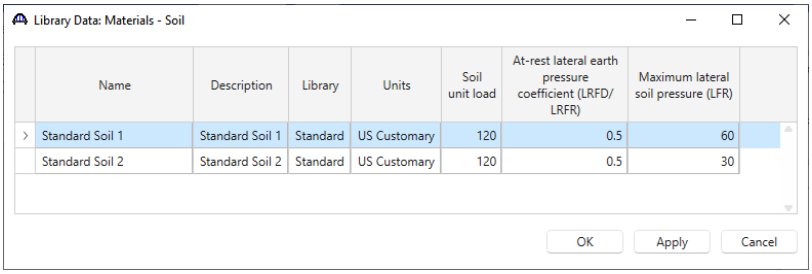
Culvert Loads

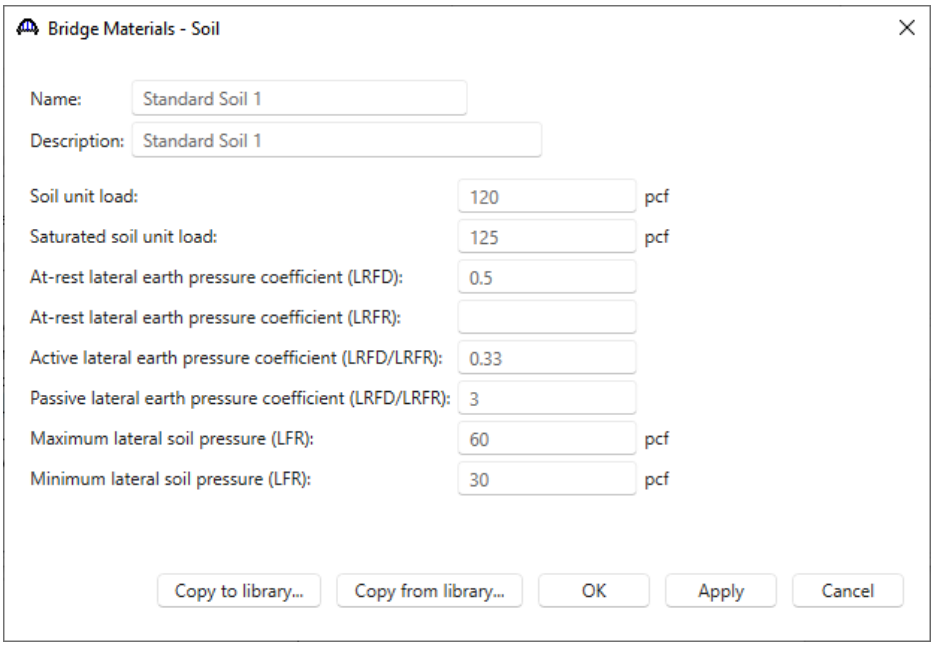
Double-click on the **Culvert Loads** node to open the **Culvert Loads** window. Define the water unit load and soil material in the **Culvert Loads** window. If the soil material is already defined within this bridge, it will show up in the dropdown list of **Soil material.** In this case, since a soil material is not defined, use the **Create new material** option to add a new soil material definition as shown below.



The **Bridge Materials - Soil** window opens as shown below. Select the **Copy from library** button to copy the **Standard Soil 1** definition from the BrDR library.

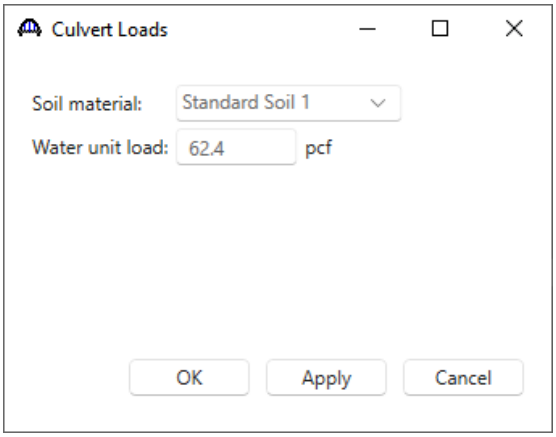






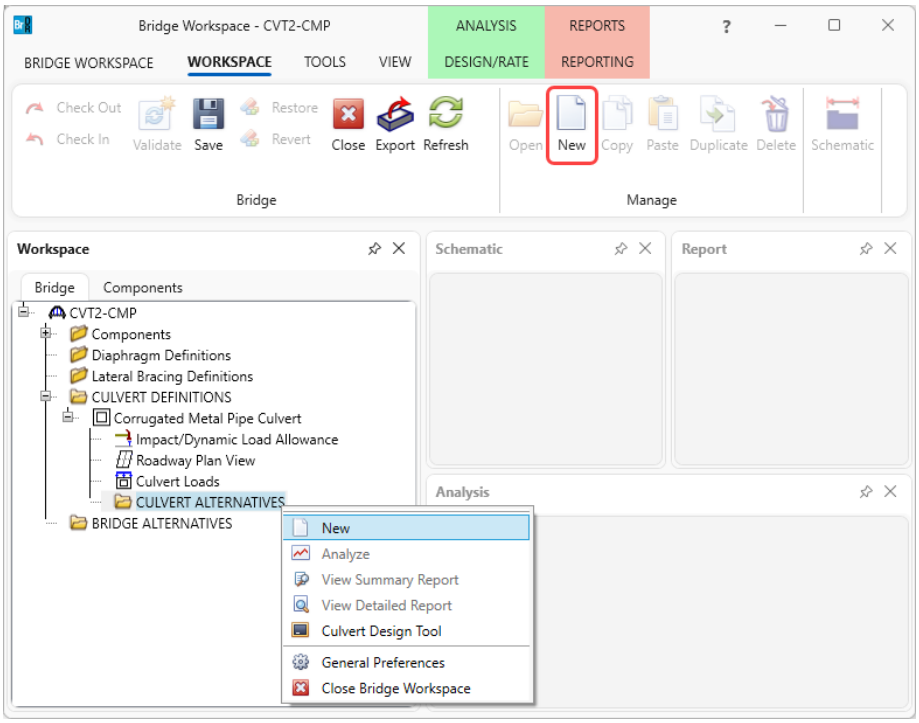
Click **OK** to create and apply this soil material in the Culvert Loads window.

Save the **Culvert Loads** window with the soil material definition and water unit load. The water unit load will populate by default as 62.4 lb/ft^3.



Culvert Alternative

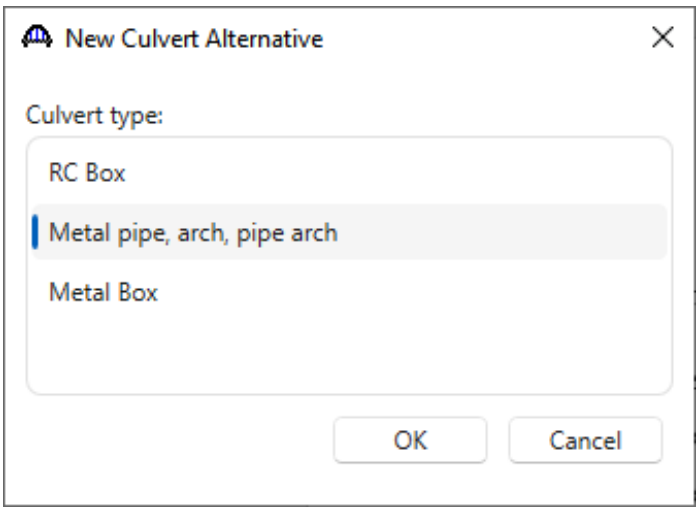
To create a new culvert alternative, click on **CULVERT ALTERNATIVES** in the **Bridge Workspace** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or double click on the **CULVERT ALTERNATIVES,** or right click and select **New).**



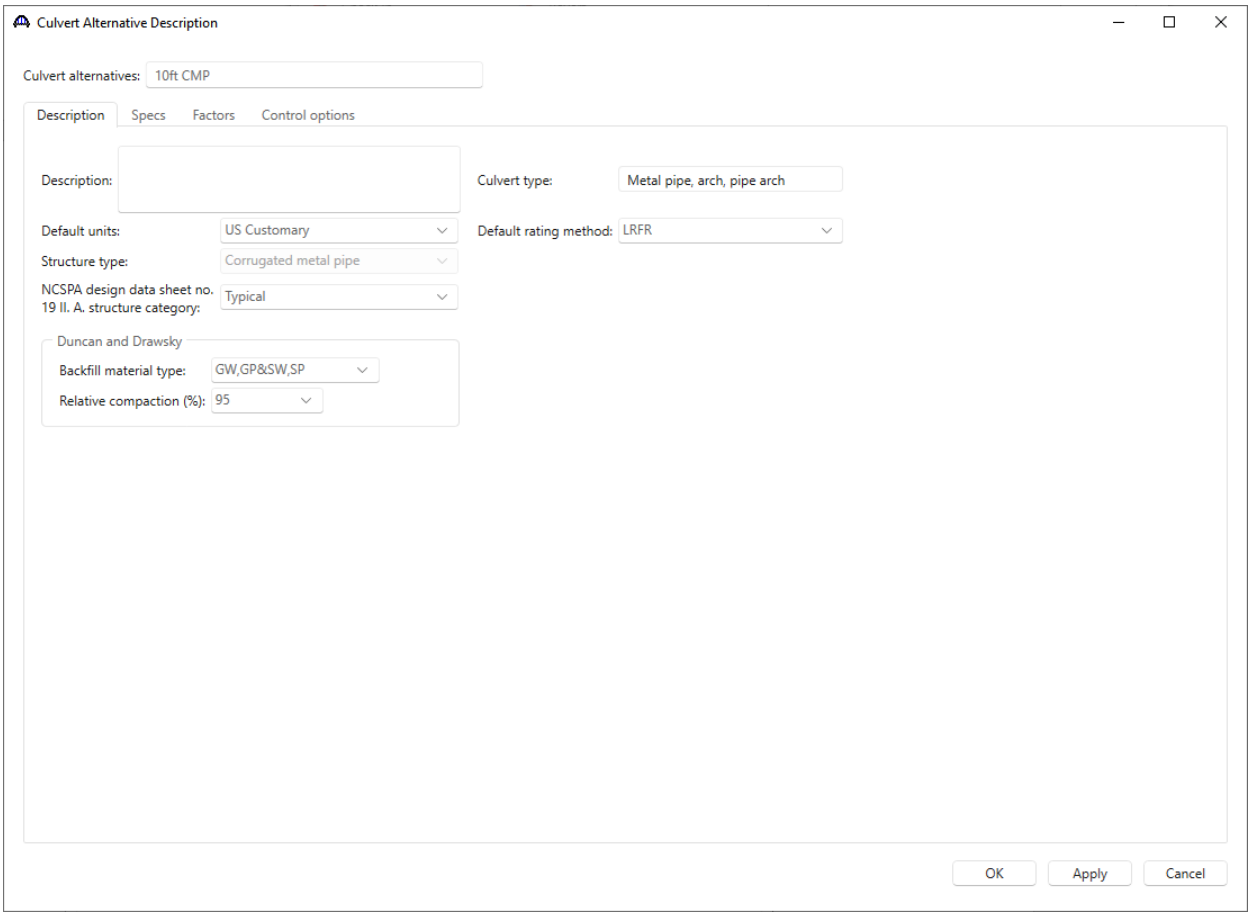
There are three culvert types available in BrDR.

1. Reinforced Concrete Box
2. Metal Pipe, arch, pipe arch
3. Metal box

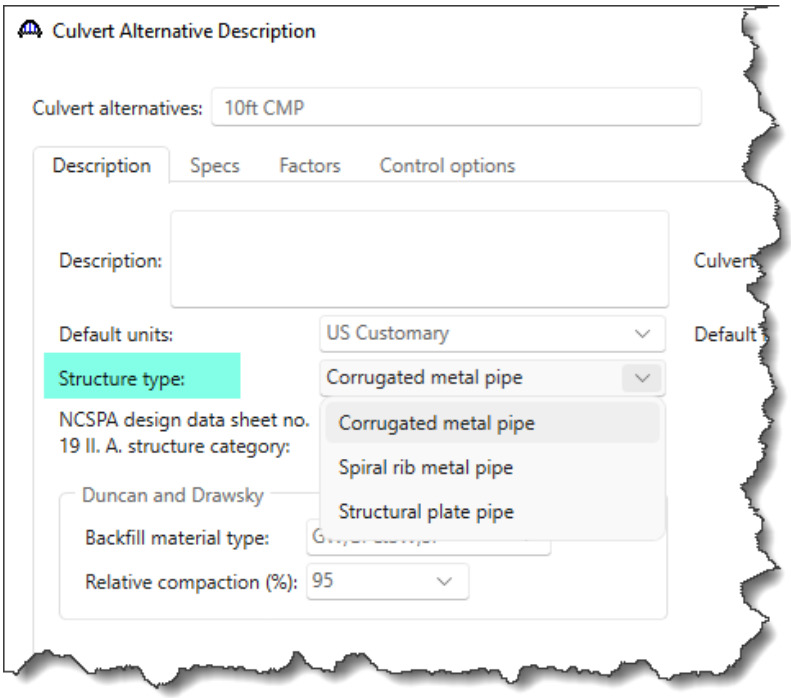
For a corrugated metal pipe culvert, select **Metal pipe, arch, pipe arch** from the available options. The culvert type selection cannot be modified after a culvert alternative is created.



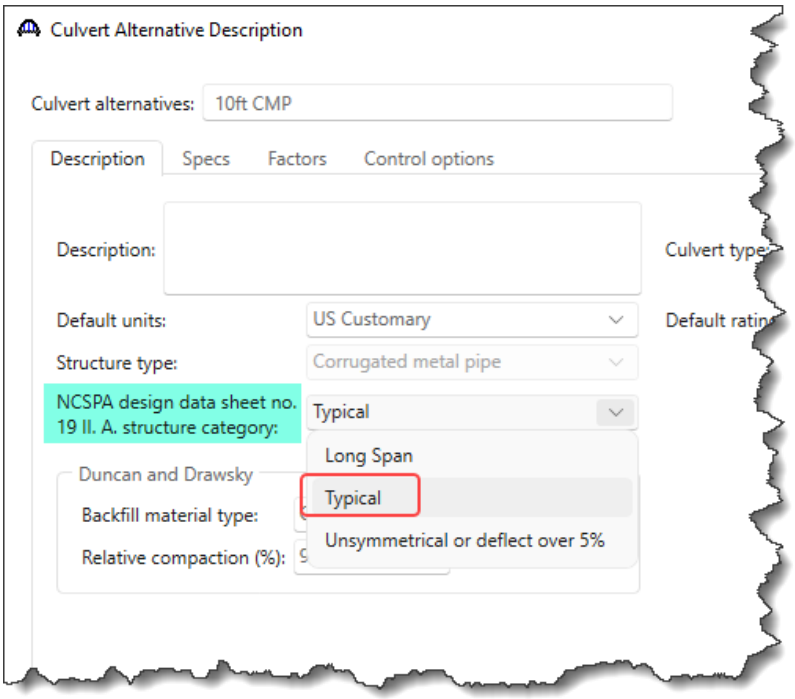
Enter the cuvlert alternative description as shown below.



Metal pipe culverts have three available **Structure types**. The type must be selected when creating a new metal pipe culvert alternative and cannot be modified after the alternative is created.

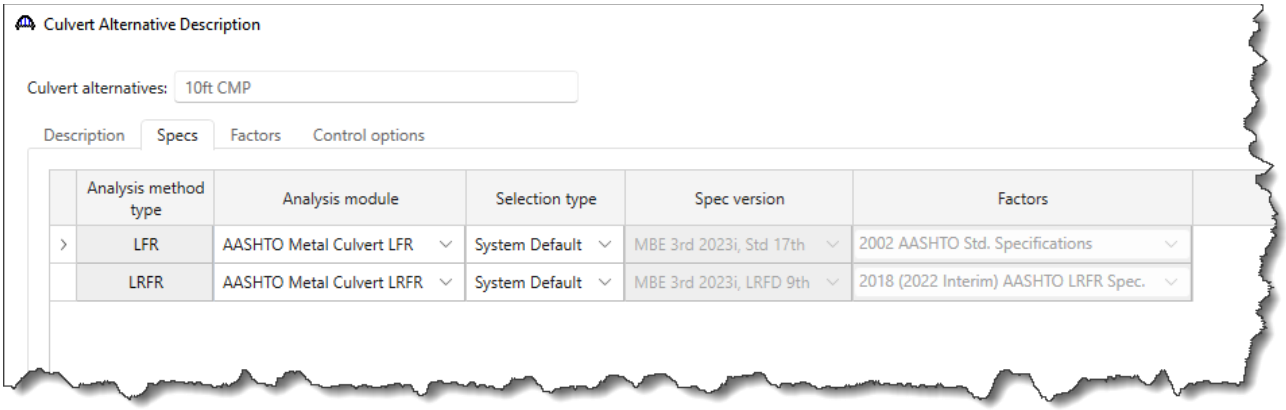


Select **Typical** under the **NCSPA design data sheet no. 19 II. A structure category**.

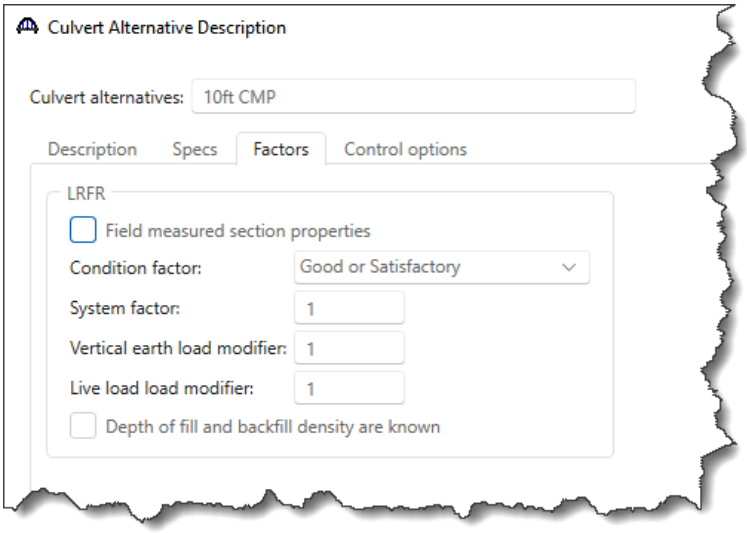


Review the information in each of the tabs of the **Culvert Alternative Description** window.

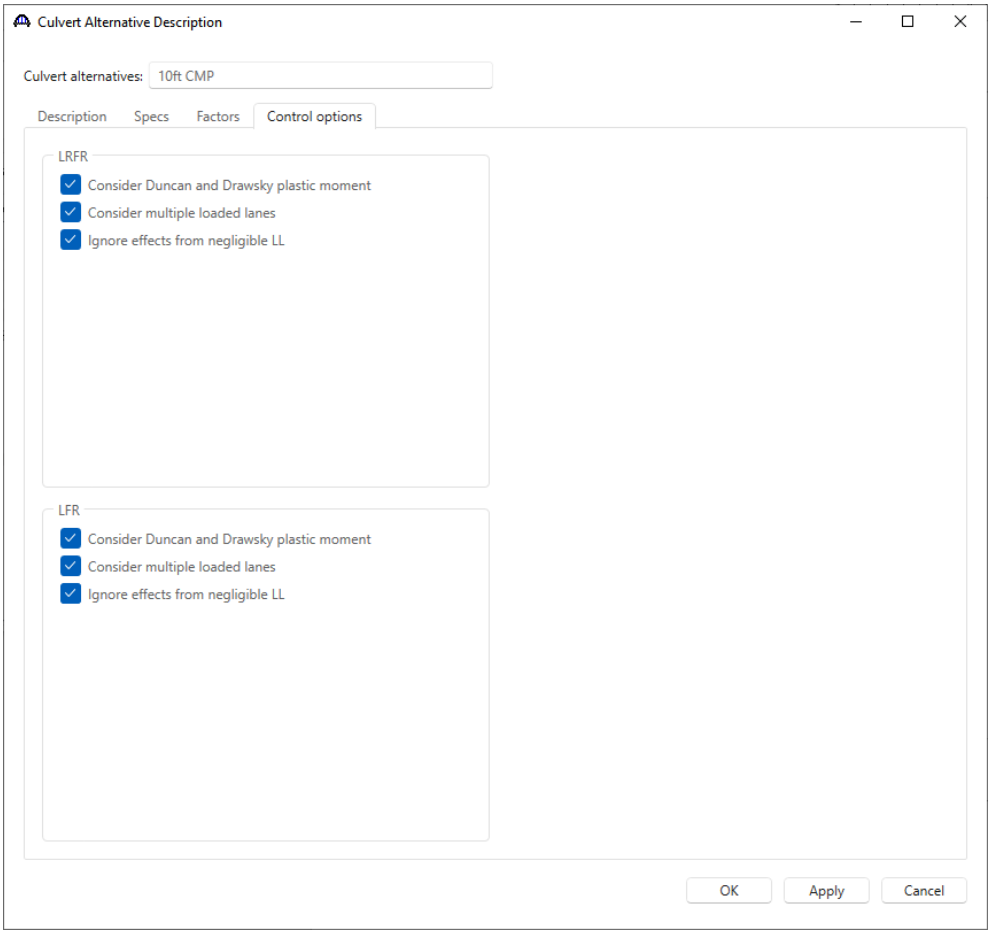
The **Specs** tab shows the analysis modules and specification versions for each analysis method type. The AASHTO metal culvert engine supports LFR and LRFR analysis method types. For both LFR and LRFR, only the MBE 3rd edition 2022 approved ballot items and newer specification versions will be available. Leave the selection set to **System Default** to use the default specification version.



The **Factors** tab provides input to modify the **LRFR** factors. The default options are reasonable to use for this example.



The **Control options** tab has advanced analysis options for LFR and LRFR analysis methods. By default, none of the options are selected. For this example, select all the control options.

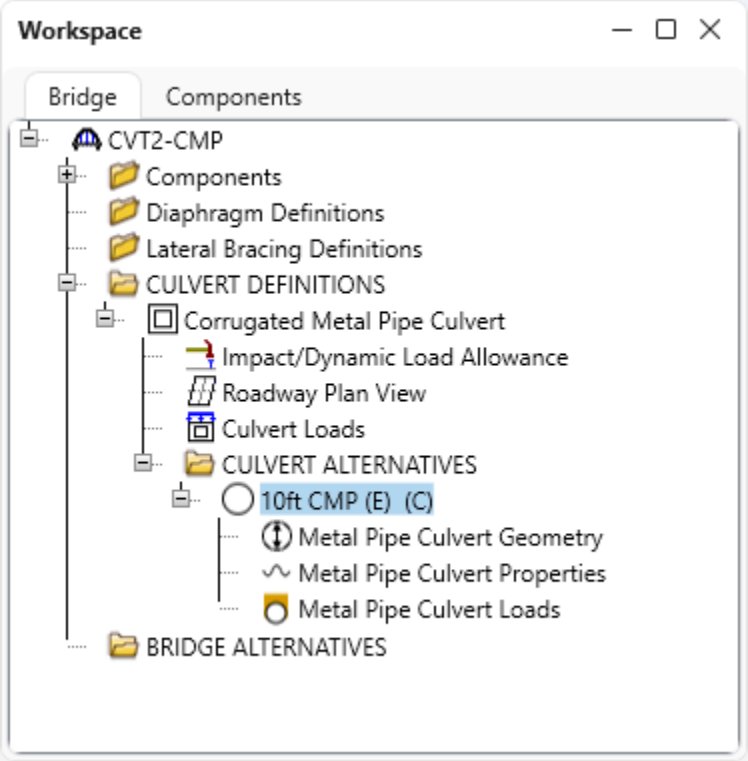


Description of Metal Pipe Culvert Alternative control options:

1. Consider Duncan and Drawsky plastic moment – Select this option to load rate a culvert alternative using the plastic moment capacity in addition to the wall capacity. The plastic moment capacity is computed according to the method described in *Design Procedures for Flexible Metal Culvert Structures* by J. M. Duncan and R. H. Drawsky (1983).
2. Consider multiple loaded lanes – This option considers multiple loaded lanes in the live load pressure calculations.
3. Ignore effects from negligible live load – Use this control option to skip the rating when live load pressure at the depth of the culvert is less than 10% of the total pressure at the depth of the culvert.

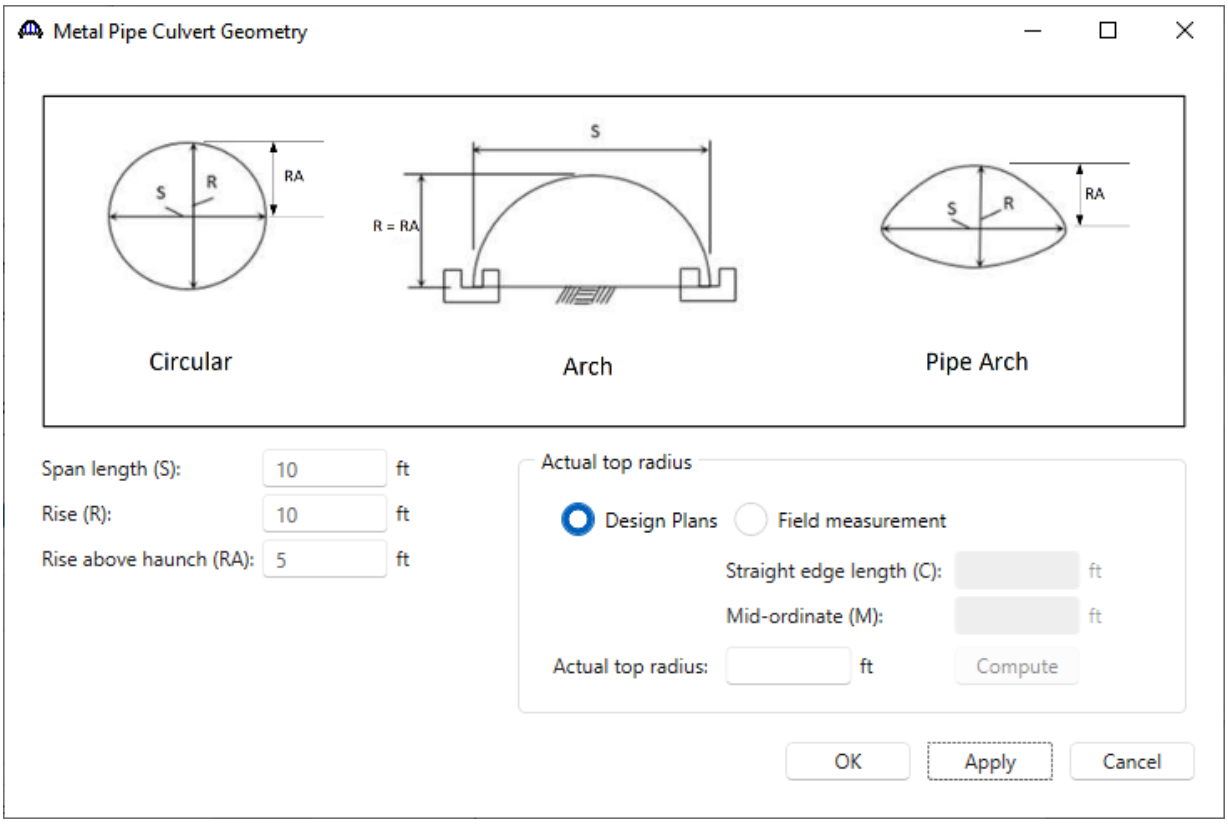
Click **OK** to create a new culvert alternative and close the window.

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



Metal Pipe Culvert Geometry

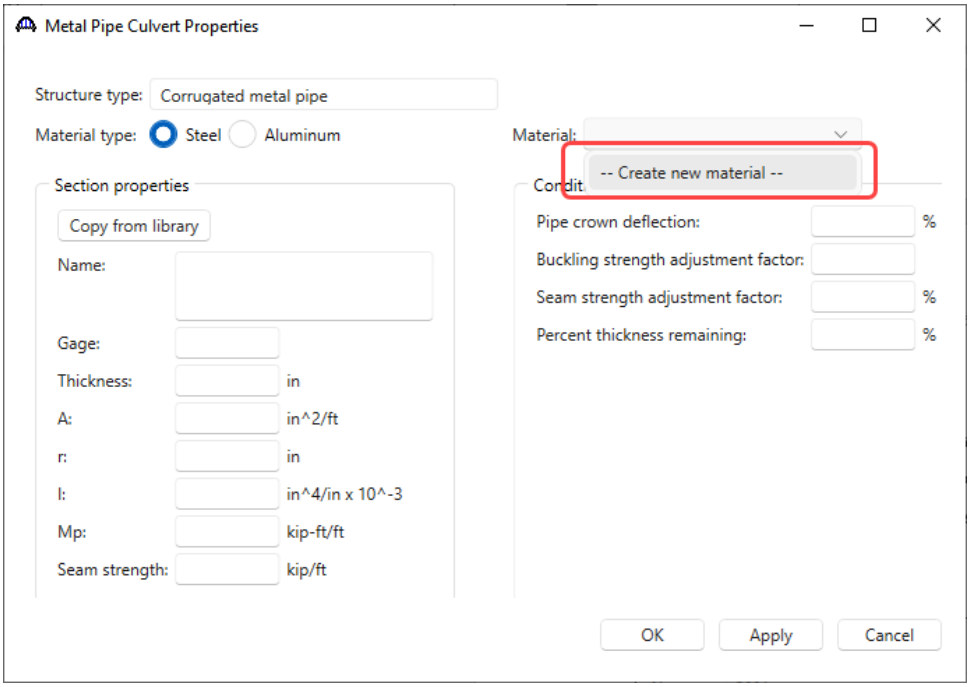
Double click on the **Metal Pipe Culvert Geometry** node in the **Bridge Workspace** tree to open the **Metal Pipe Culvert Geometry** window to enter the culvert geometry. Refer to the diagrams included in the window for the dimensions of the specific metal pipe culvert structure you are entering. For the corrugated metal pipe in this example, the dimensions correspond to the circular pipe diagram. This example is a **Typical** structure category type, but when **Long span**, or **Unsymmetrical or Deflect over 5%** are selected under the **NCSPA design data sheet no. 19 II. A structure category** in the **Culvert Alternative Description - Description** window, the actual top radius must also be input.



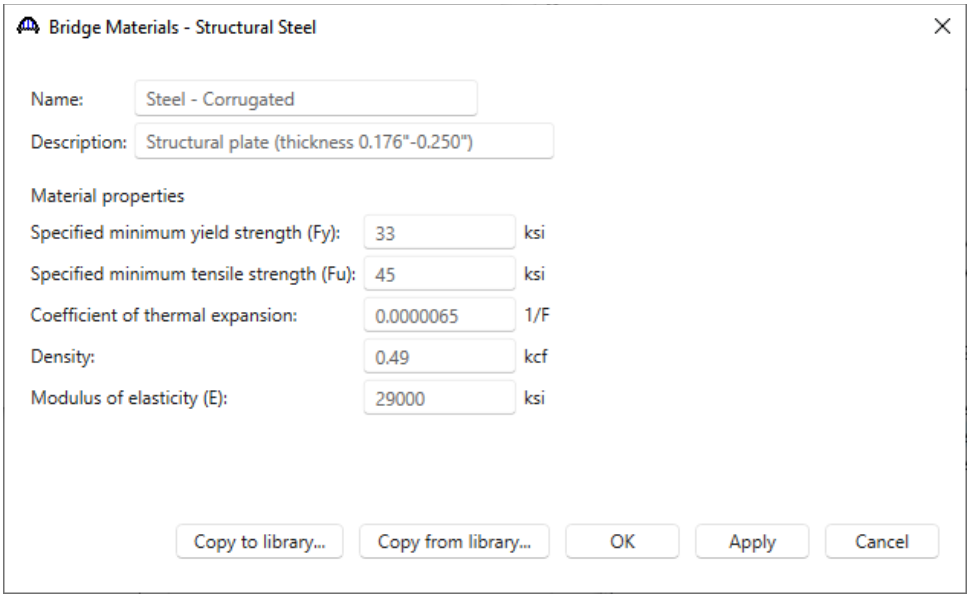
Click **OK** to apply the data and close the window.

Metal Pipe Culvert Properties

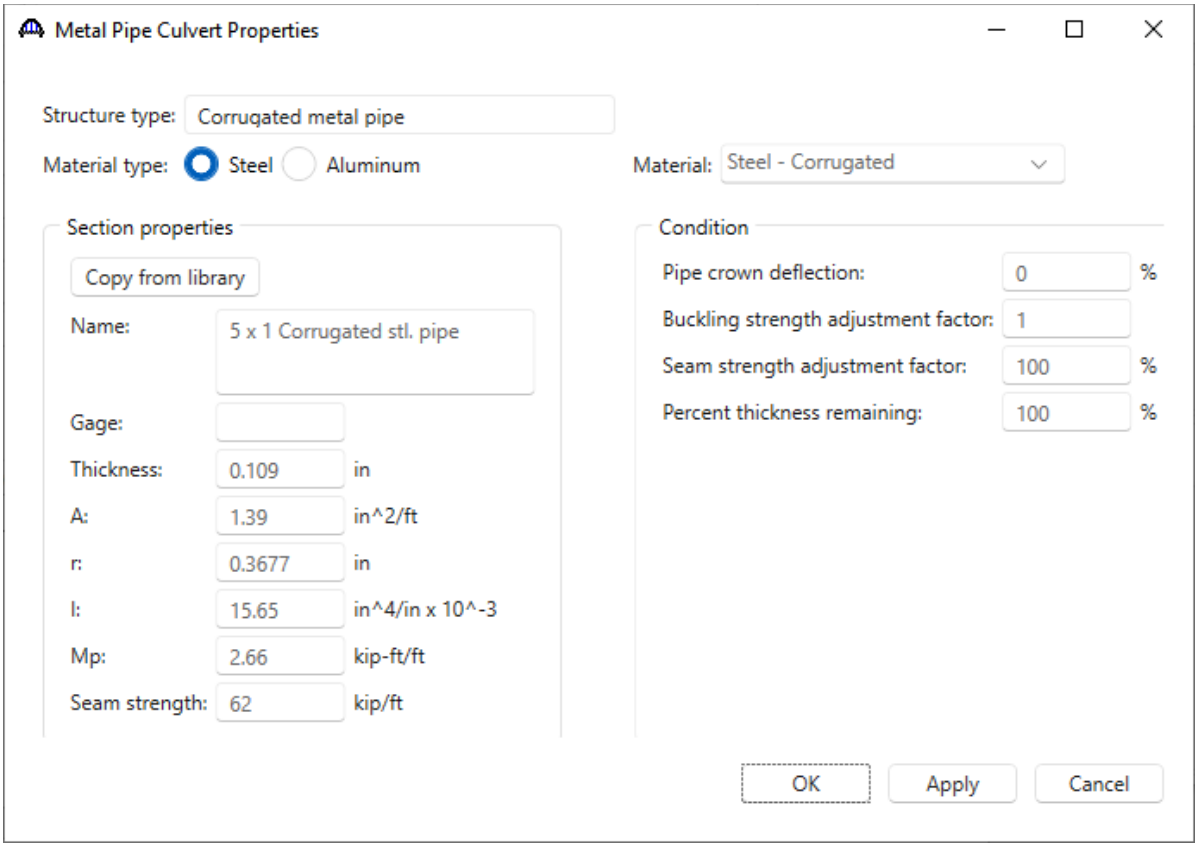
Double-click on the **Metal Pipe Culvert Properties** node in the **Bridge Workspace** tree to enter the pipe culvert section properties, material, and culvert condition. Both steel and aluminum materials are available for the metal pipe culverts. First, select **Steel** and use the **Create new material** option from the material dropdown list to define a steel material.



Use the **Copy from library…** option to copy the **Steel - Corrugated** structural steel material definition. Select OK to save the new steel material.



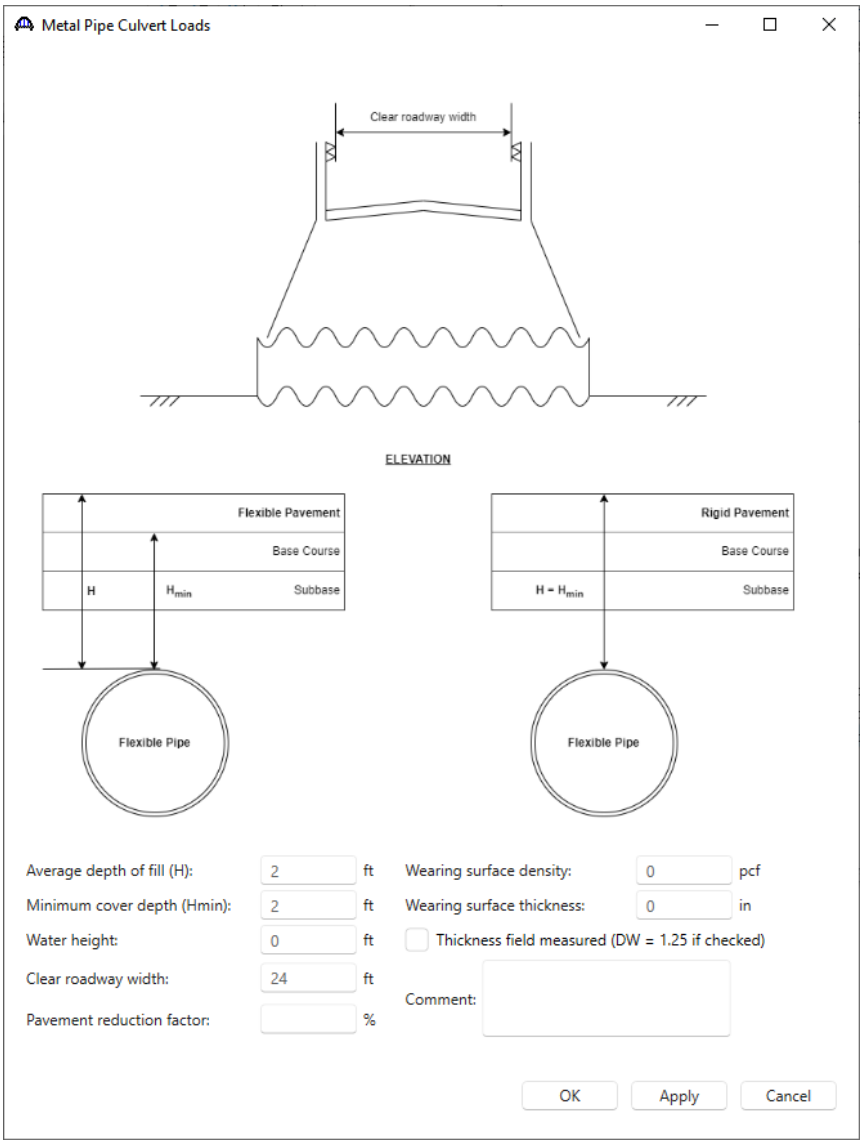
Input the section properties and condition for the corrugated steel pipe as shown below.



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

Metal Pipe Culvert Loads

Double-click on the **Metal Pipe Culvert Loads** node in the **Bridge Workspace** tree to enter details about the metal pipe culvert loads in the **Metal Pipe Culvert Loads** window. Since the control option for **Consider multiple loaded lanes** is selected, the **Clear roadway width** input will be used to determine the number of lanes. The **Pavement reduction factor** is an input item introduced in the 2022 approved ballot item specification revisions. If applying the **Pavement reduction factor**, enter the factor as a percent by which you want to reduce the live load pressure. If the input is left blank, the AASHTO Metal Culvert Engine will apply a factor of 100%, or in other words 100% of the live load pressure will be applied to the culvert.

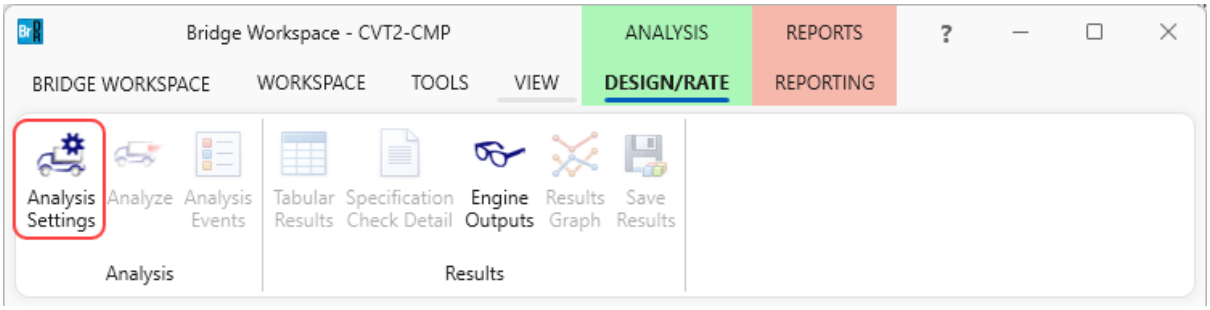


This completes the data entry for the corrugated metal pipe culvert structure.

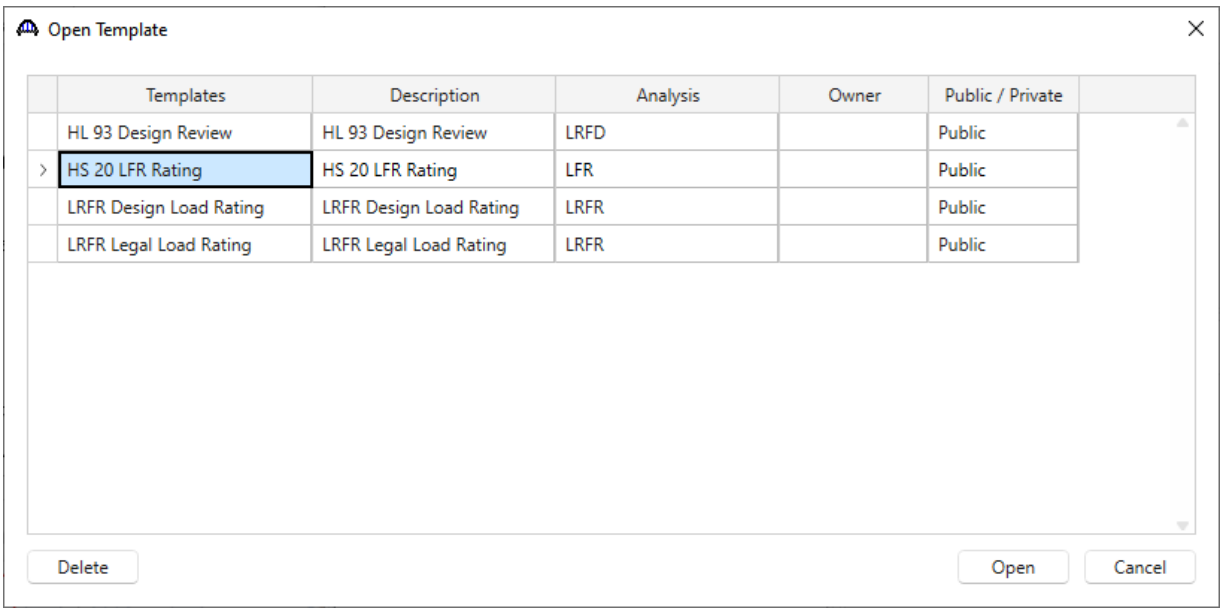
Corrugated Metal Pipe Culvert LFR Analysis.

LFR Analysis

To perform an LFR Rating, select the **10ft CMP** alternative in the **Bridge Workspace** tree and click the **Analysis Settings** button from the **Analysis** group of the **DESIGN/RATE** ribbon.

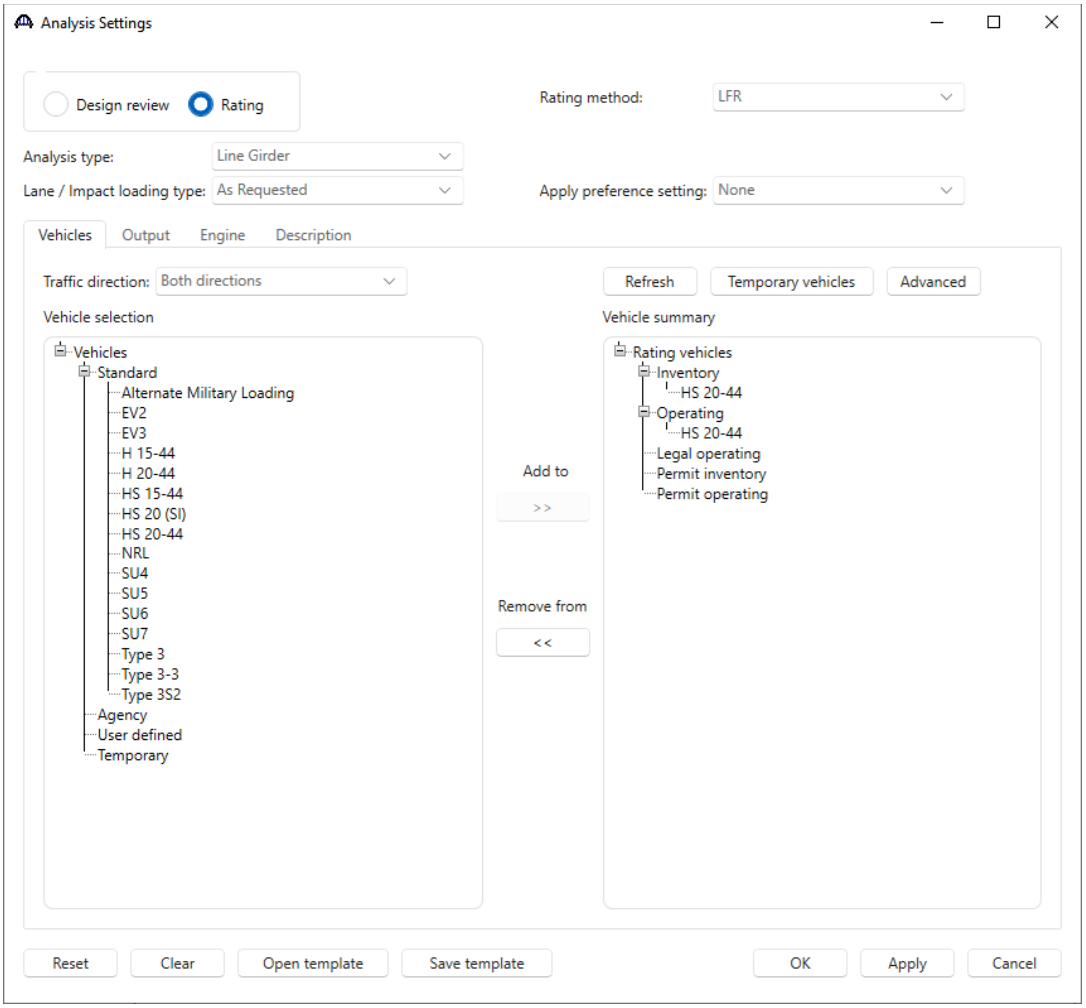


The **Analysis Settings** window will open. Click the **Open template** button and select the **HS 20 LFR Rating** to be used in the rating and click **Open**.

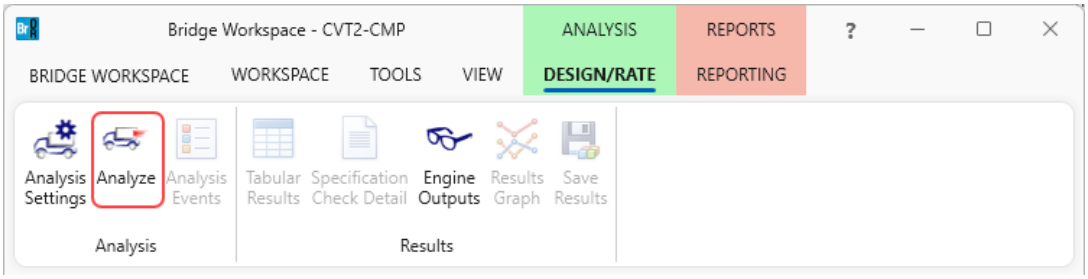


Click **OK** to apply the data and close the window.

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

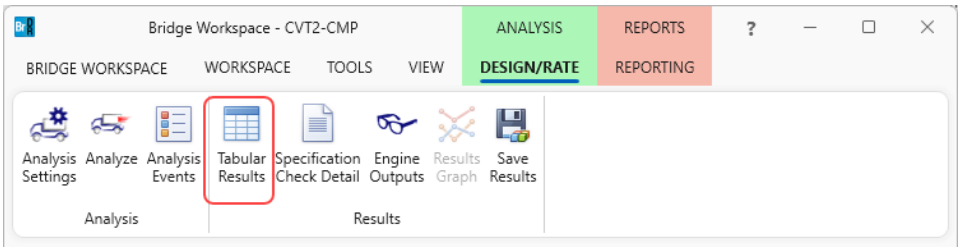


Click the **Analyze** button from the **Analysis** group of the **DESIGN/RATE** ribbon to start the rating process.

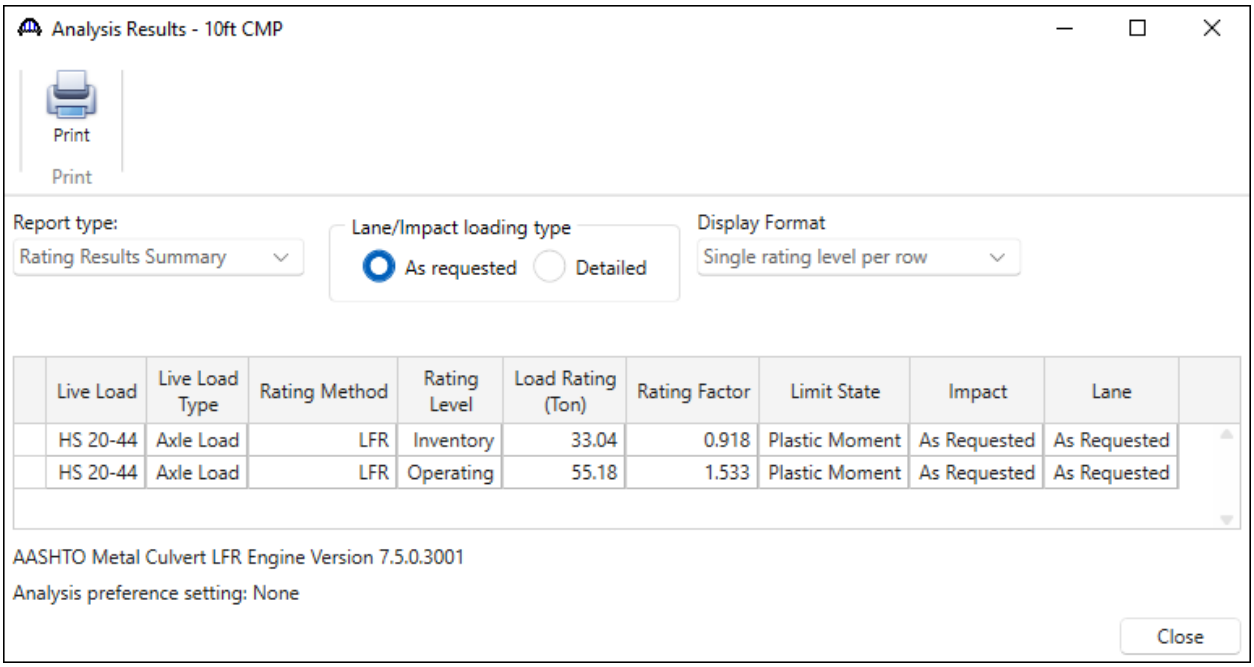


Tabular Results

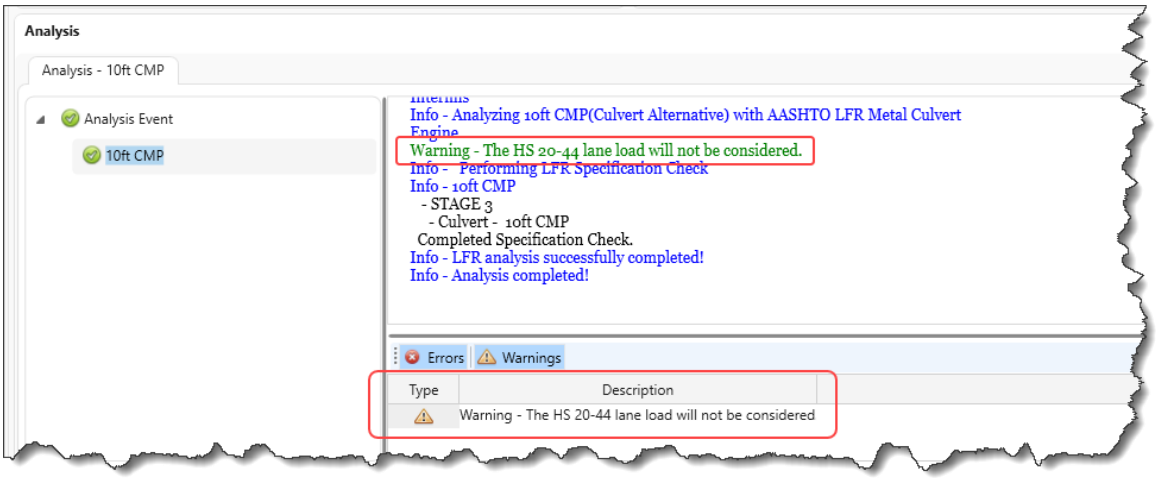
When the rating is completed, results can be reviewed by clicking the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon.



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. The **Rating Results Summary** is the only report type available following a metal culvert analysis.

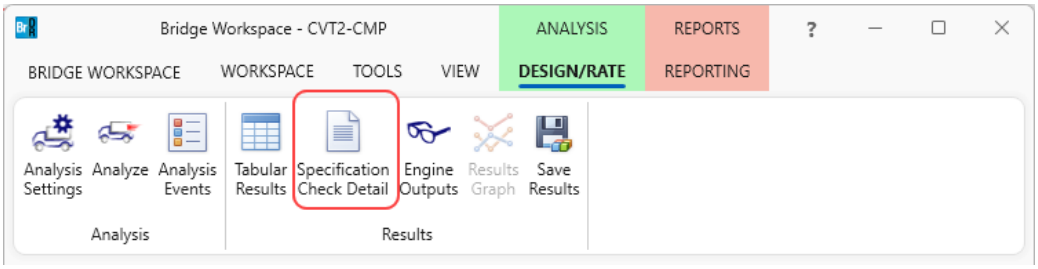


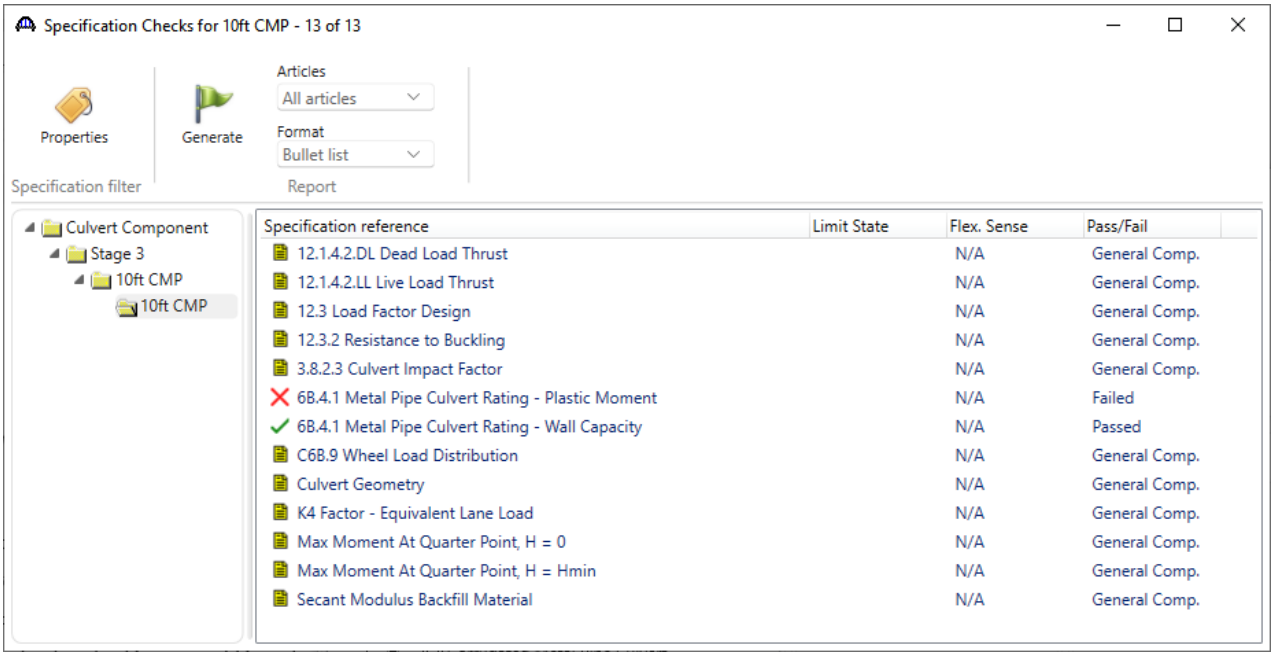
Review the **Analysis Progress** log shown below. The warning shown informs that the lane load portion of the HS 20-44 vehicle is not considered for the metal culvert analysis. Some advanced vehicle loading options are not applicable to the metal culvert analysis including lane loads, adjacent vehicles, fatigue trucks, and tandem trains.



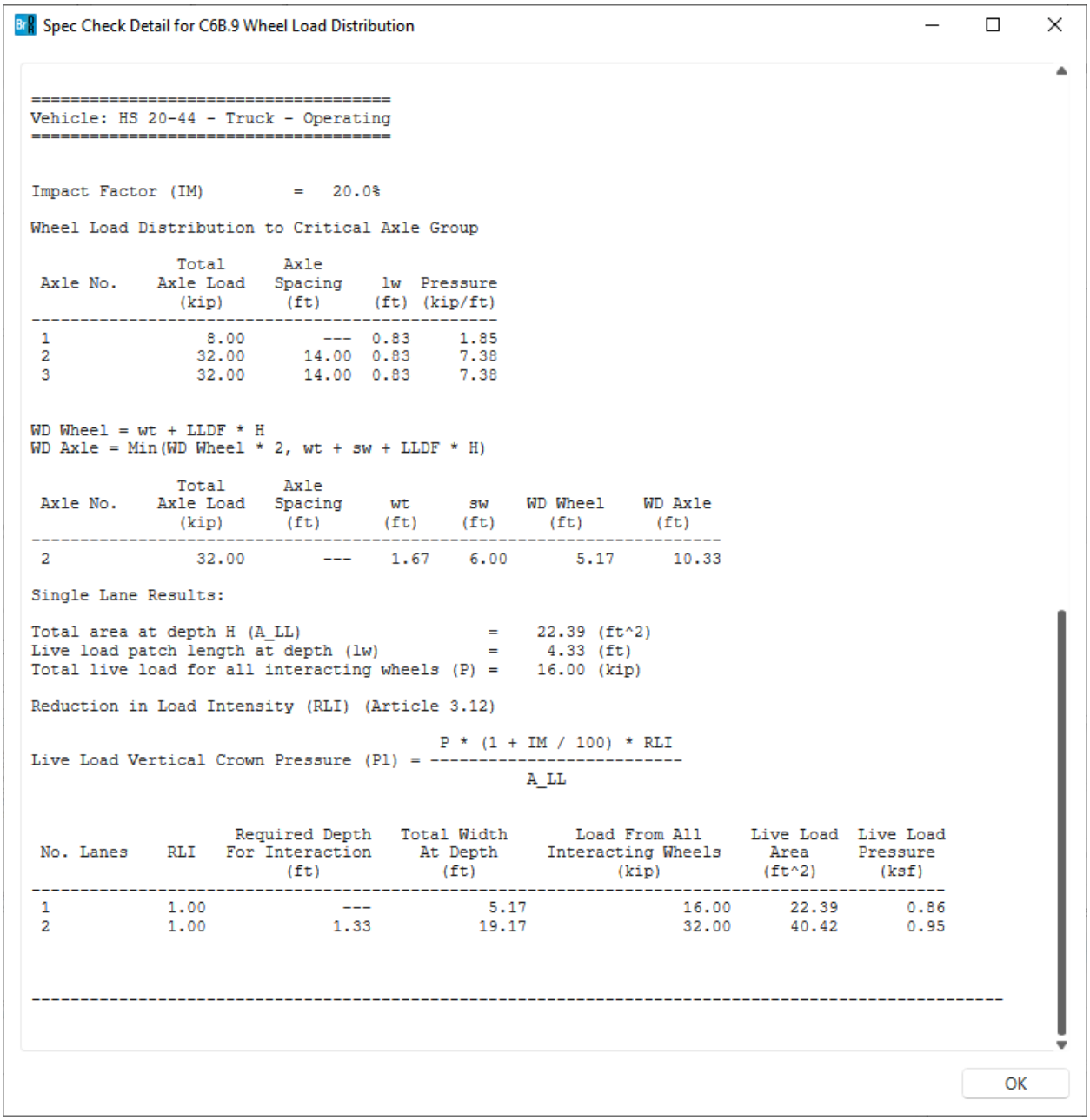
Specification Check Detail

To review detailed rating results at the controlling location, use the **Specification Check Detail** button in the ribbon to open the **Specification** window. Note that the metal culvert only has one POI for specification checking. The 6B.4.1 Metal Pipe Culvert Rating – Plastic Moment rating article and the last four calculation articles listed are included because the LFR control option for Duncan and Drawsky plastic moment was selected.





Open the **C6B.9 Wheel Load Distribution** specification article to display detailed calculations for the LFR vehicle live loading. This article includes calculations for each vehicle and each analysis category. The live load pressure calculations are shown below for the HS 20-44 truck in the operating analysis category.

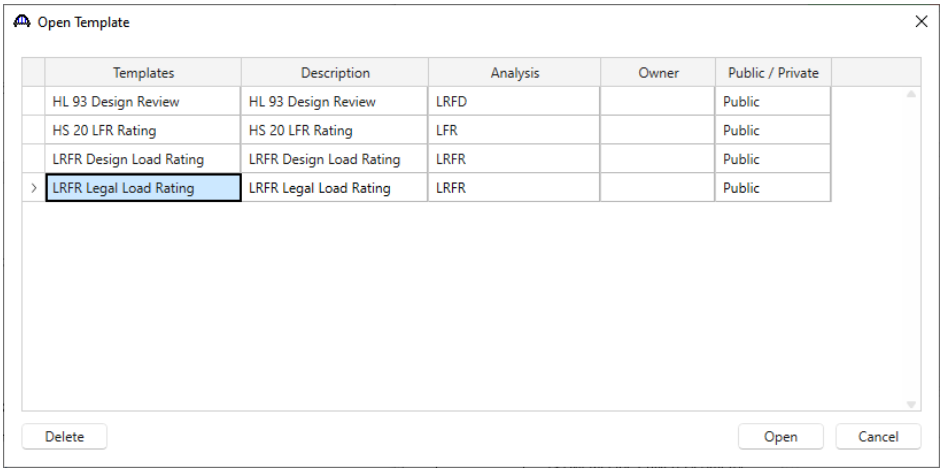



```
====================================
Vehicle: HS 20-44 - Truck - Operating
====================================


Impact Factor (IM)         =   20.0%

Wheel Load Distribution to Critical Axle Group

               Total      Axle
 Axle No.    Axle Load   Spacing     lw  Pressure
               (kip)      (ft)      (ft) (kip/ft)
-----------------------------------------------
 1               8.00        ---  0.83     1.85
 2              32.00      14.00  0.83     7.38
 3              32.00      14.00  0.83     7.38


WD Wheel = wt + LLDF * H
WD Axle = Min(WD Wheel * 2, wt + sw + LLDF * H)

               Total      Axle
 Axle No.    Axle Load   Spacing     wt      sw    WD Wheel    WD Axle
               (kip)      (ft)      (ft)    (ft)     (ft)       (ft)
-------------------------------------------------------------------------
 2              32.00        ---    1.67    6.00       5.17      10.33

Single Lane Results:

Total area at depth H (A_LL)                  =    22.39 (ft^2)
Live load patch length at depth (lw)          =     4.33 (ft)
Total live load for all interacting wheels (P) =    16.00 (kip)

Reduction in Load Intensity (RLI) (Article 3.12)

                                        P * (1 + IM / 100) * RLI
Live Load Vertical Crown Pressure (Pl) = --------------------------
                                                 A_LL


                    Required Depth   Total Width       Load From All     Live Load  Live Load
 No. Lanes    RLI   For Interaction     At Depth     Interacting Wheels     Area     Pressure
                         (ft)             (ft)              (kip)          (ft^2)      (ksf)
-------------------------------------------------------------------------------------------
 1            1.00             ---          5.17               16.00      22.39       0.86
 2            1.00            1.33         19.17               32.00      40.42       0.95


-------------------------------------------------------------------------------------------------------
```

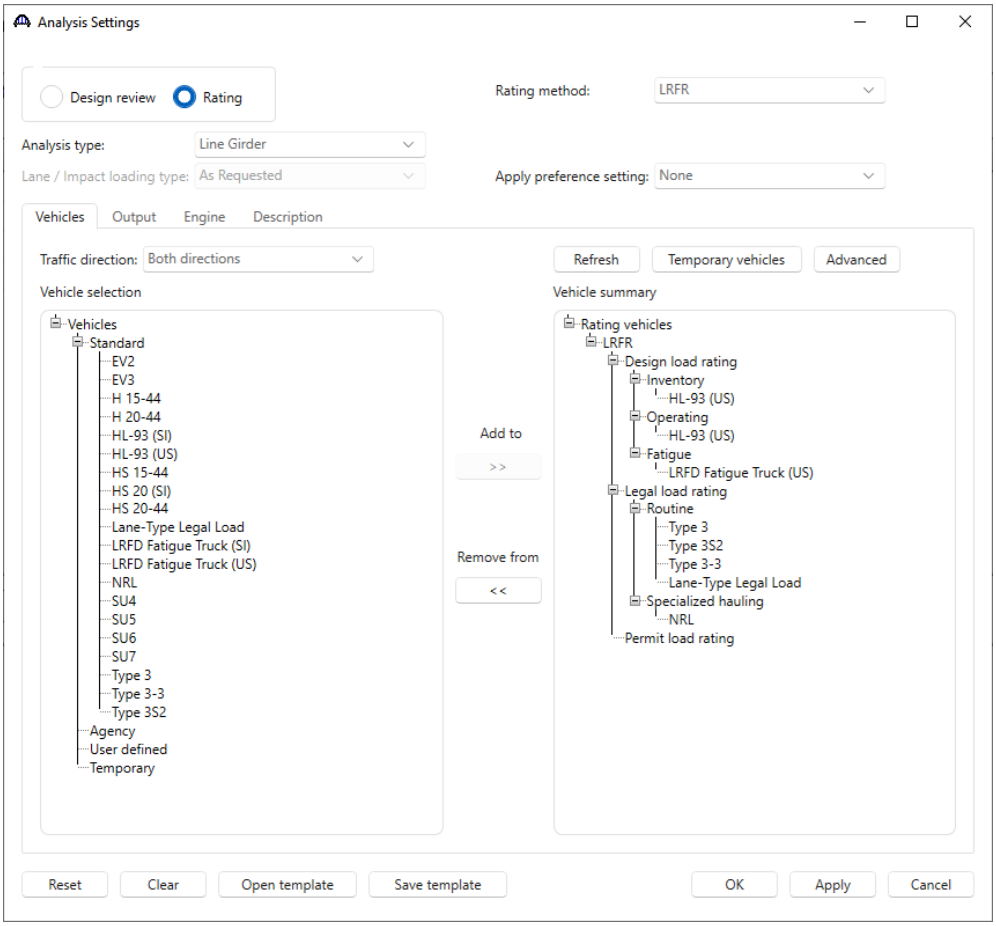
Corrugated Metal Pipe Culvert LRFR Analysis.

LRFR Analysis

Close the spec check window and reopen the **Analysis Settings** window to test an **LRFR** analysis. Click the **Open template button** and select the **LRFR Legal Load Rating** to be used in the rating and click **Open**.

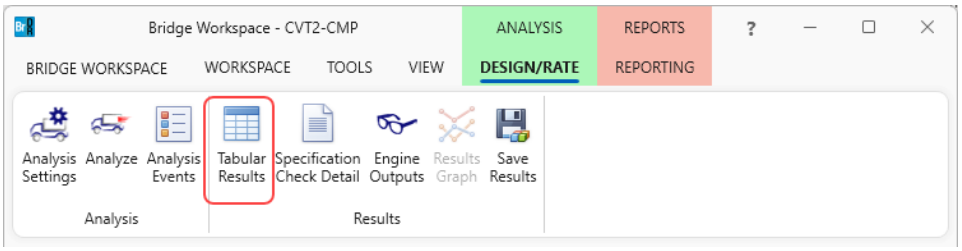


The **Analysis Settings** window will be populated as shown below.

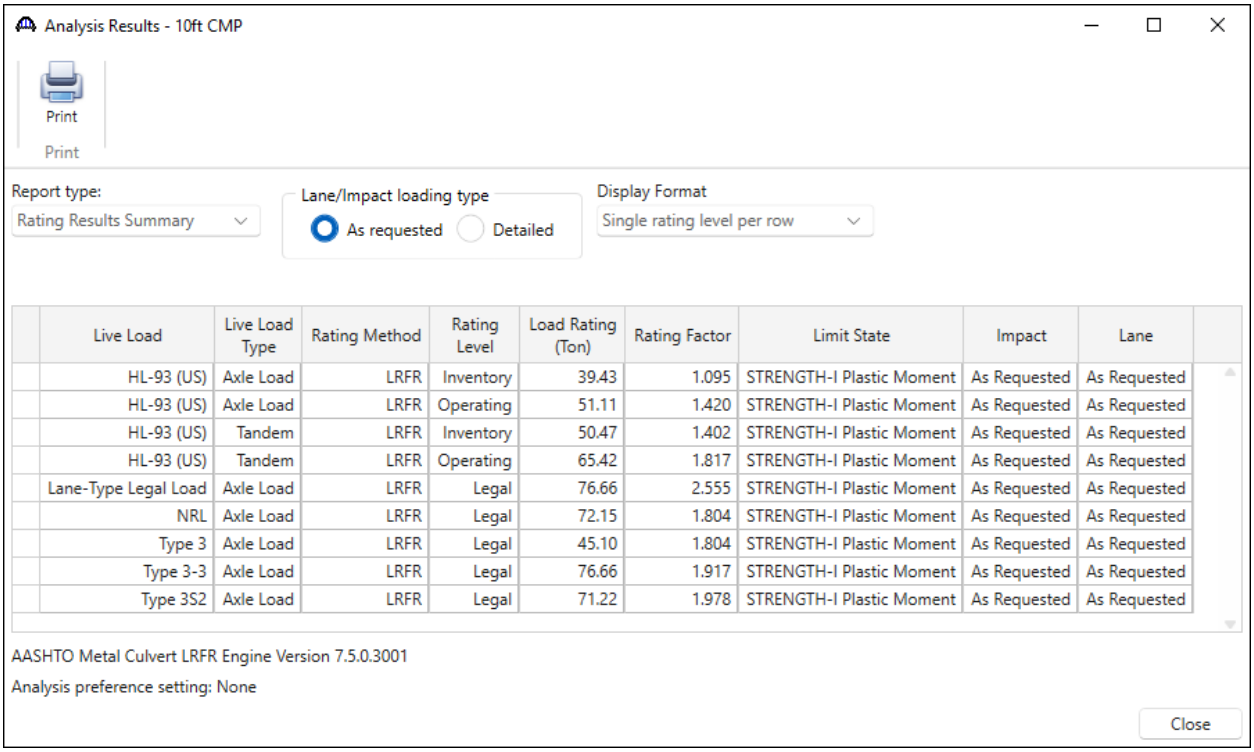


Click **OK** to apply the settings and close the window.

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

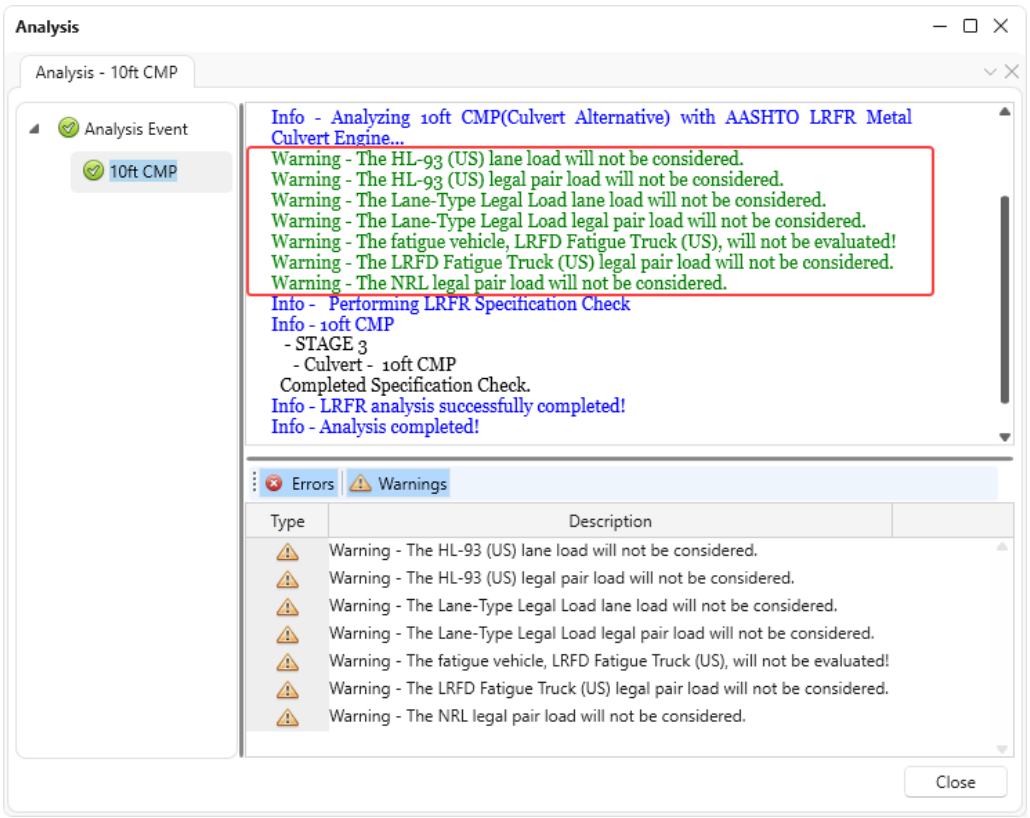


The window shown below will open. Select **Single rating level per row** as the display format to display the output in single rows as shown below. The **Rating Results Summary** is the only report type available following a metal culvert analysis.



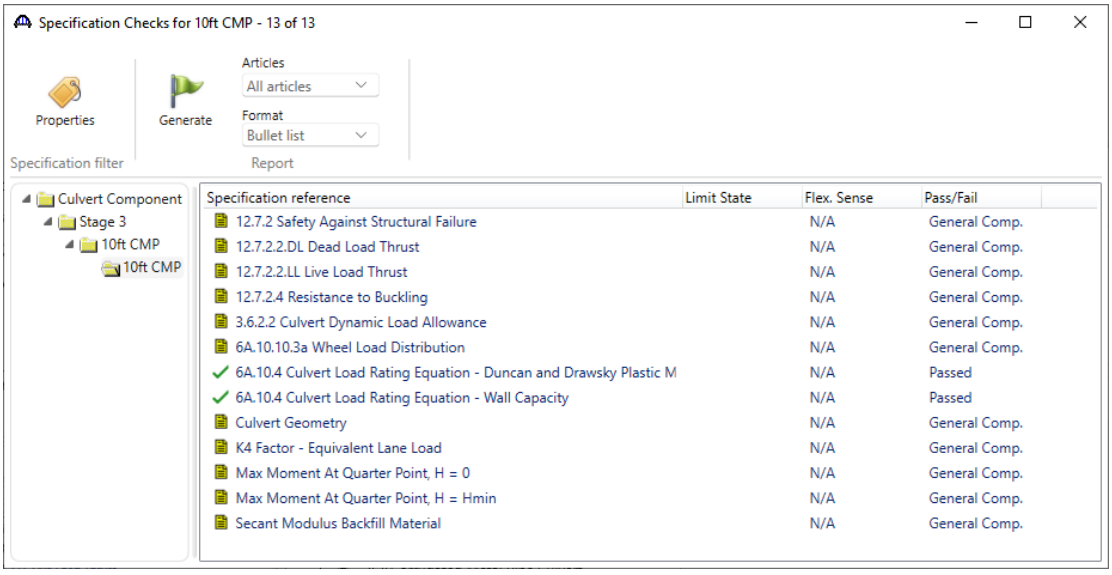
Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Limit State	Impact	Lane
HL-93 (US)	Axle Load	LRFR	Inventory	39.43	1.095	STRENGTH-I Plastic Moment	As Requested	As Requested
HL-93 (US)	Axle Load	LRFR	Operating	51.11	1.420	STRENGTH-I Plastic Moment	As Requested	As Requested
HL-93 (US)	Tandem	LRFR	Inventory	50.47	1.402	STRENGTH-I Plastic Moment	As Requested	As Requested
HL-93 (US)	Tandem	LRFR	Operating	65.42	1.817	STRENGTH-I Plastic Moment	As Requested	As Requested
Lane-Type Legal Load	Axle Load	LRFR	Legal	76.66	2.555	STRENGTH-I Plastic Moment	As Requested	As Requested
NRL	Axle Load	LRFR	Legal	72.15	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
Type 3	Axle Load	LRFR	Legal	45.10	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
Type 3-3	Axle Load	LRFR	Legal	76.66	1.917	STRENGTH-I Plastic Moment	As Requested	As Requested
Type 3S2	Axle Load	LRFR	Legal	71.22	1.978	STRENGTH-I Plastic Moment	As Requested	As Requested

Review the **Analysis Progress** log . As with the LFR analysis, the warnings shown informs that some of the selected loads are not appliable to metal culverts. See sample below.

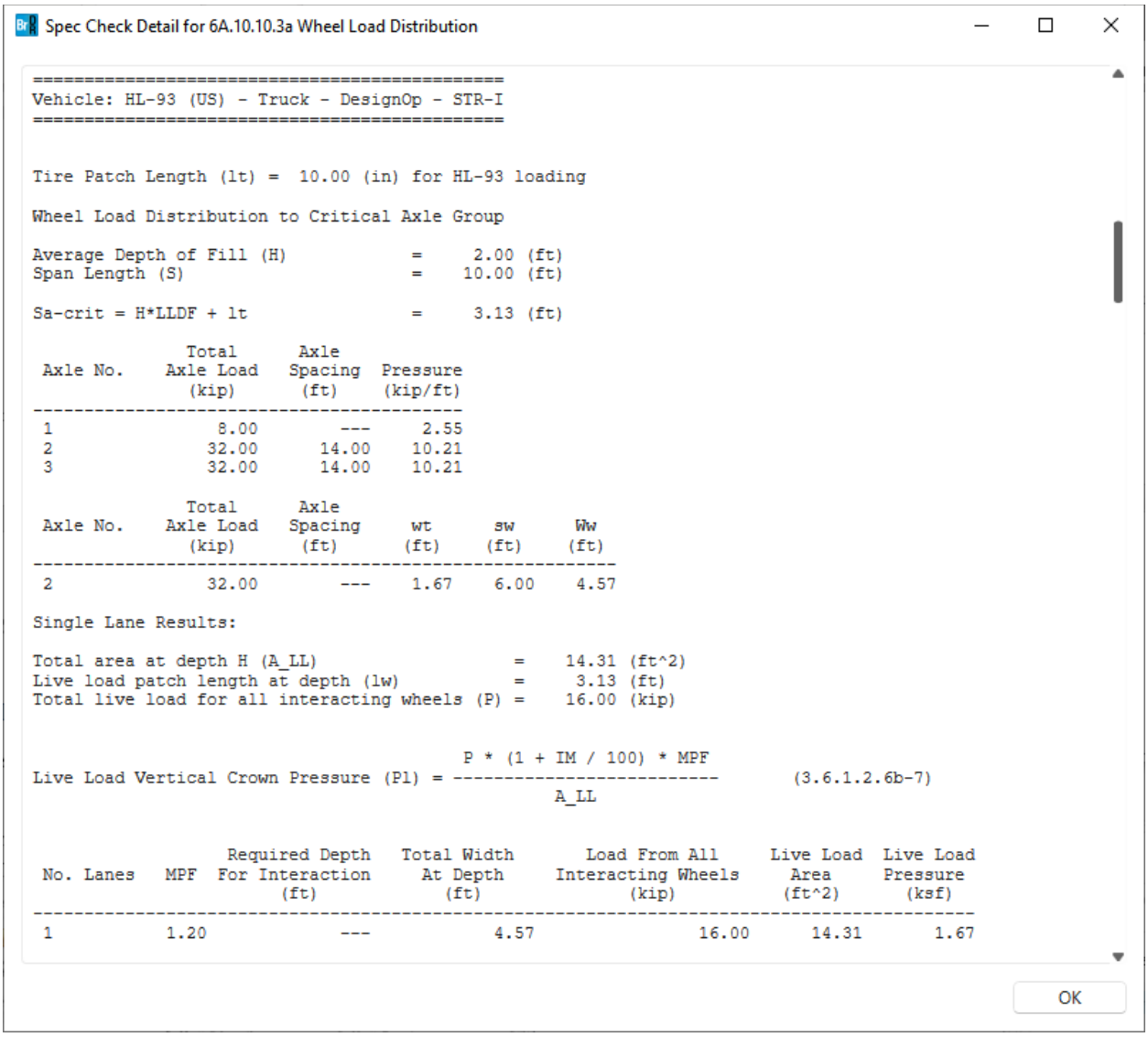


Specification Check Detail

To review detailed rating results at the controlling location, click on the **Specification Check Detail** button in the ribbon to open the **Specification Checks** window. Note that the metal culvert only has one POI for specification checking. The **6A.10.4 Culvert Load Rating Equation – Duncan and Drawsky Plastic Moment** rating article and the last four calculation articles listed are included because the LRFR control option for Duncan and Drawsky plastic moment as selected.



Open the **6A.10.10.3a Wheel Load Distribution** specification article for detailed calculations for the LRFR vehicle live loading. This article includes calculations for each vehicle and each analysis category. The live load pressure calculations are shown below for the HL-93 truck in the operating analysis category.




```
================================================
Vehicle: HL-93 (US) - Truck - DesignOp - STR-I
================================================


Tire Patch Length (lt) =  10.00 (in) for HL-93 loading

Wheel Load Distribution to Critical Axle Group

Average Depth of Fill (H)            =     2.00 (ft)
Span Length (S)                      =    10.00 (ft)

Sa-crit = H*LLDF + lt                =     3.13 (ft)

               Total      Axle
 Axle No.    Axle Load   Spacing  Pressure
               (kip)      (ft)    (kip/ft)
-----------------------------------------
 1               8.00        ---     2.55
 2              32.00      14.00    10.21
 3              32.00      14.00    10.21

               Total      Axle
 Axle No.    Axle Load   Spacing     wt      sw      Ww
               (kip)      (ft)      (ft)    (ft)    (ft)
-------------------------------------------------------
 2              32.00        ---    1.67    6.00    4.57

Single Lane Results:

Total area at depth H (A_LL)                  =    14.31 (ft^2)
Live load patch length at depth (lw)          =     3.13 (ft)
Total live load for all interacting wheels (P) =    16.00 (kip)


                                      P * (1 + IM / 100) * MPF
Live Load Vertical Crown Pressure (Pl) = -------------------------       (3.6.1.2.6b-7)
                                                 A_LL


                  Required Depth   Total Width       Load From All     Live Load  Live Load
 No. Lanes   MPF  For Interaction     At Depth     Interacting Wheels     Area     Pressure
                        (ft)            (ft)              (kip)          (ft^2)     (ksf)
-------------------------------------------------------------------------------------------
 1           1.20            ---           4.57               16.00      14.31       1.67
```