AASHTOWare BrDR 7.5.0 Culvert Tutorial CVT2 – Corrugated Metal Pipe Culvert Example

Topics Covered

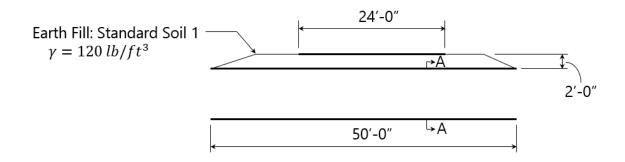
- Metal Pipe Culvert Alternatives
- LFR Rating
- LRFR Rating
- MBE 2022 approved ballot item specification updates

Overview of Metal Pipe Culvert features

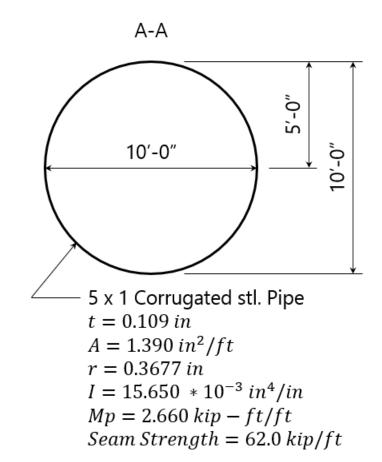
- Metal pipe culverts implemented in BrDR version 7.3.0 in September 2022
- Metal pipe culverts support LFR and LRFR rating methods
- Metal pipe culverts can be rated for wall capacity and plastic moment
- Single and multilane loading options available

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



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.

Br 🖁	AASHTOWare	e Bridge D	esign and Ra	ating	?	_		\times
BRIDGE EXPLORER BRID	GE FOLDER	RATE	TOOLS	VIEW				
New Open C Batch ~ Bridge	Find Copy P	aste Cop To Manage	From) Delete				
New (Ctrl+N) Creates a new bridge.		BID	Br	idge ID				
		3	TrainingBrid	ge3		Trainin	g Bridge	3(LI 🔺
🖻 🏓 All Bridges		4	PCITrainingB	ridge1		PCI Tra	iningBrid	lge1
Image: Image		5	PCITrainingB	ridge2		PCITra	iningBrid	ge2
Deleted Bridges		6	PCITrainingB	ridge3		PCI Tra	ainingBrid	lge3
		7	PCITrainingB	ridge4		PCITra	iningBrid	ge4

New Bridge							- 🗆	
Bridge ID: CVT2-CMP	9	NBI struc	ture ID (8): CVT2-CMP		Template Bridge compl	etely defined	Bridge Workspace View Superstructures Culverts Substructures	
Description Desc	ription (cont'd)	Alternativ	es Global reference point	Traffic	Custom agency fie	lds		
Name:	CVT2-Corrugated	l Metal Pip	e Culvert		Year built:	2022		
Description:	Example corrugat	ted metal j	pipe culvert structure					
Location:	Pittsburgh, PA				Length:		ft	
Facility carried (7):					Route number:			
Feat. intersected (6):					Mi. post:			
Default units:	US Customary	~						
Bridge associa	ation V B	irR 🗹 B	rD 🗍 BrM					
						ОК	Apply Canc	el

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.

Br	Bridge Worksp	pace - CVT2	-CMP		AN	ALYSIS	REP	ORTS		?	_		×
BRIDGE WORKSPA	CE WOR	KSPACE	TOOLS	VIEW	DESI	GN/RATE	REPO	RTING					
n Check Out	/alidate Save	Constant of the sector of the	· • •	Export	Refresh	Open	New		Paste nage	Duplicate) Delete	Schemati	c
Workspace		x x	chematic				× ×	Repor	rt.			2	> ×
Bridge Comp CVT2-CMP Compo Compo Diaphra Lateral	onents	s											
🗁 BRIDGE	ALTERNATIVE											×	×
		Q View	Summary F Detailed Ri ral Preferer Bridge Wc	eport									
🕰 Culvert Defin	nition									-	_		×
Name:	Corrugate	d Metal Pi	ipe Culve	rt									
Description:													
Default units:	US Custom	ary	~										
Existing	Current	Culvert	alternativ	e name		Descr	iption						
							0	K		Apply		Cancel	

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

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

Workspace	_	×
Bridge Components		
CVT2-CMP Components Components Components Culvert Definitions CULVERT DEFINITIONS CULVERT DEFINITIONS CULVERT Management Component Impact/Dynamic Load Allowance Culvert Loads Culvert Loads CULVERT ALTERNATIVES CULVERT		

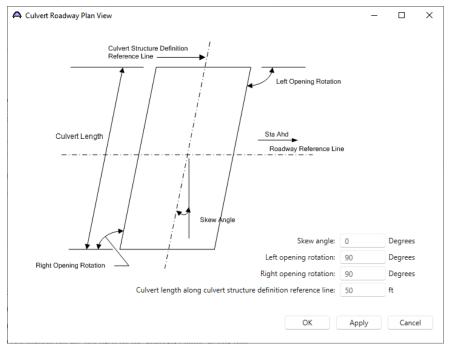
Impact/Dynamic Load Allowance

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 Definition In	npact/Dynamic Load Allowance		-		\times
Standard impact factor O Standard AASHT					
LRFD dynamic load allo	wance IM=33(1.0-0.125DE)>=0%				
	ОК	Apply		Cancel	

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.

A Culvert Loads		_		×
Soil material:	-	~		
Water unit load:	Create new ma	aterial		
			_	
	ОК Арр	ly	Cance	

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.

lame:	
escription:	
bil unit load:	pcf
aturated soil unit load:	pcf
t-rest lateral earth pressure coefficient (LRFD):	
t-rest lateral earth pressure coefficient (LRFR):	
ctive lateral earth pressure coefficient (LRFD/LRFR):	
assive lateral earth pressure coefficient (LRFD/LRFR):	
aximum lateral soil pressure (LFR):	pcf
inimum lateral soil pressure (LFR):	pcf

A	Library Data: Materials - Soil						— C	×
	Name	Description	Library	Units	Soil unit load	At-rest lateral earth pressure coefficient (LRFD/ LRFR)	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	
	Standard Soli 2 Standard Soli 2 Standard US Lustomary 120 U.S Standard Soli 2 Standard OS Customary 120 U.S Standard Soli 2 St							

lame:	Standard Soil 1		
Description:	Standard Soil 1		
oil unit load	Ŀ	120	pcf
aturated so	il unit load:	125	pcf
At-rest latera	I earth pressure coefficient (LRFD):	0.5	
At-rest latera	I earth pressure coefficient (LRFR):		
Active lateral	earth pressure coefficient (LRFD/LRFR):	0.33	
assive latera	al earth pressure coefficient (LRFD/LRFR):	3	
Maximum lat	eral soil pressure (LFR):	60	pcf
/inimum lat	eral soil pressure (LFR):	30	pcf

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/ft³.

	_		×
Standard	Soil 1 🗸 🗸		
62.4	pcf		
ОК	Apply	Cancel	
		62.4 pcf	Standard Soil 1 v 62.4 pcf

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**).

Bridge Workspace - CV	T2-CMP	ANALYSIS	REPORTS	?	_		×
BRIDGE WORKSPACE	TOOLS VIEW	DESIGN/RATE	REPORTING				
	estore 🔀 🎸 evert Close Export	Refresh Open	New Copy P	aste Duplicate) Delete	Schemati	c
bridge			IVIGII	age			
Workspace	× &	Schematic	\$? ×	Report		Ś	×
Corponents Components Diaphragm Definitions Diaphragm Definitions Diaphragm Definitions Corrugated Metal Pipe Cult Diapart/Dynamic Load A Diapart/Dynamic Load A Diapart/Dynamic Load A							
Culvert Loads		Analysis				Ś	×
- 🔁 BRIDGE ALTERNATIVES	New Analyze View Summary R View Detailed Re Culvert Design Tr General Preferent Close Bridge Wo	port ces					

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.

A New Culvert Alternative		×
Culvert type:		
RC Box		
Metal pipe, arch, pipe arch	1	
Metal Box		
	ОК	Cancel
	UK	Cancer

Enter the cuvlert alternative description as shown below.

A Culvert Alternation	ve Description						-		×
Culvert alternatives	s: 10ft CMP								
Description	Specs Facto	ors Control options							
Description:			Culvert type:	Metal pipe, arch, pipe arch					
Default units:		US Customary \checkmark	Default rating method:	LRFR	\sim				
Structure type:		Corrugated metal pipe \sim							
NCSPA design d 19 II. A. structur	data sheet no. 'e category:	Typical \checkmark							
C Duncan and [
Backfill mate		GW,GP&SW,SP ∨							
Relative com	paction (%): 9	95 ~							
						OK Appl	y	Cance	1

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.

Culvert alternative	es: 10ft CMP			
Description	Specs Facto	ors Control options		
Description:				Culver
Default units:		US Customary	~	Defaul
Structure type:		Corrugated metal pipe	\sim	
-	data sheet no.	Corrugated metal pipe		
19 II. A. structu	ire category:	Spiral rib metal pipe		
Duncan and	Drawsky	Structural plate pipe		1
Backfill mat	erial type:	3,		
Relative cor	mpaction (%):	95 ~		1

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

Culvert alternatives: 10ft CMF)		
Description Specs Fac	ctors Control options		
Description:			Culvert typ
Default units:	US Customary	~	Default rat
Structure type:	Corrugated metal pipe		1
NCSPA design data sheet no 19 II. A. structure category:	• Typical	\sim	
Duncan and Drawsky Backfill material type: Relative compaction (%):	Long Span Typical Unsymmetrical or deflect over	er 5%	4

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.

eso	cription 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 \sim
	LRFR	AASHTO Metal Culvert LRFR 🗸 🗸	System Default 🗸	MBE 3rd 2023i, LRFD 9th 🖂	2018 (2022 Interim) AASHTO LRFR Spec. 🗸

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

vert alternatives: 10ft CMF)
Description Specs Fa	ctors Control options
LRFR	
Field measured section	on properties
Condition factor:	Good or Satisfactory \sim
System factor:	1
Vertical earth load modifie	er: 1
Live load load modifier:	1
Depth of fill and back	fill density are known

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.

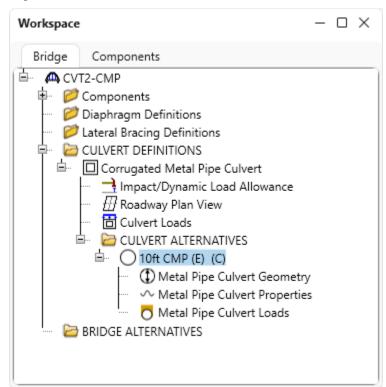
A Culvert Alternative Description				_		×
Culvert alternatives: 10ft CMP						
Description Specs Factors	Control options					
LRFR Consider Duncan and Draws Consider multiple loaded lar Ignore effects from negligib	nes					
LFR Consider Duncan and Draws Consider multiple loaded lar Ignore effects from negligib	nes					
			ОК	Apply	Cance	el

Description of Metal Pipe Culvert Alternative control options:

- 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.

Metal Pipe Culvert Geor	netry				_		×
SR	RA		s		S R	RA	
Circular			Arch	Pi	pe Arch		
Span length (S):	10	ft	Actual top radius				
Rise (R):	10	ft	O Design Plans	Field measurement	:		
Rise above haunch (RA):	5	ft		Straight edge length (C):		ft	
				Mid-ordinate (M):		ft	
			Actual top radius:	ft	Compute		
				ОК	Apply	Cancel	

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.

tructure type: Corrug	ated metal pipe		
Naterial type: 🔘 Stee	el 🔷 Aluminum	Material: Condit Create new material	
Copy from library		Pipe crown deflection:	
Name:		Buckling strength adjustment factor:	
		Seam strength adjustment factor:	
Gage:		Percent thickness remaining:	
Thickness:	in		
A:	in^2/ft		
r:	in		
l:	in^4/in x 10^-3		
Mp:	kip-ft/ft		
Seam strength:	kip/ft		

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

erials - Structural Steel					;
Steel - Corrugated					
Structural plate (thickness 0	0.176"-0.250")				
perties					
nimum yield strength (Fy):	33	ksi			
nimum tensile strength (Fu):	45	ksi			
f thermal expansion:	0.0000065	1/F			
	0.49	kcf			
lasticity (E):	29000	ksi			
Copy to library	Copy from lib	rary	OK	Apply	Cancel
	Steel - Corrugated Structural plate (thickness (perties himum yield strength (Fy): himum tensile strength (Fu): f thermal expansion: lasticity (E):	Steel - Corrugated Structural plate (thickness 0.176"-0.250") perties nimum yield strength (Fy): 33 nimum tensile strength (Fu): 45 i thermal expansion: 0.0000065 0.49 lasticity (E): 29000	Steel - Corrugated Structural plate (thickness 0.176"-0.250") perties nimum yield strength (Fy): 33 simum tensile strength (Fu): 45 if thermal expansion: 0.0000065 1/F 0.49 kcf elasticity (E): 29000 ksi	Steel - Corrugated Structural plate (thickness 0.176"-0.250") perties nimum yield strength (Fy): 33 nimum tensile strength (Fu): 45 ksi 0.0000065 1/F 0.49 kcf elasticity (E): 29000	Steel - Corrugated Structural plate (thickness 0.176"-0.250") perties nimum yield strength (Fy): 33 simum tensile strength (Fu): 45 ksi 0.0000065 1/F 0.49 kcf elasticity (E): 29000

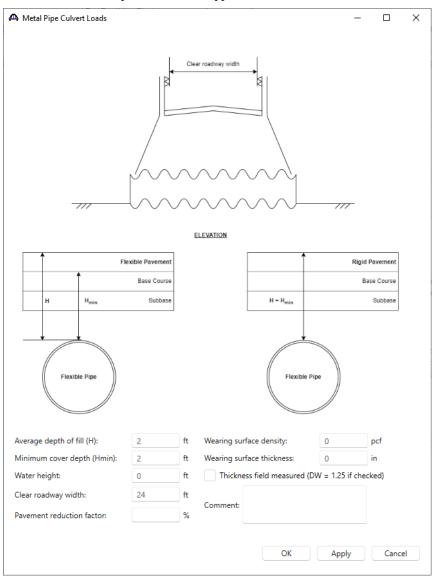
Structure type: C	orrugated m	netal pipe				
Material type: 🔘	Steel	Aluminum	Material:	Steel - Corrugated	\sim	
Section properti	es		- Condit	ion		
Copy from lib	rary		Pipe c	rown deflection:	0	
Name:	5 x 1 Corr	ugated stl. pipe	Buckli	ng strength adjustment factor:	1	
			Seam	strength adjustment factor:	100	
Gage:			Percer	nt thickness remaining:	100	
Thickness:	0.109	in				
A:	1.39	in^2/ft				
r	0.3677	in				
l:	15.65	in^4/in x 10^-3				
Mp:	2.66	kip-ft/ft				
Seam strength:	62	kip/ft				

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.

Bridge Bridge	Workspace - CVT2-CMP		ANALYSIS	REPORTS	?	_	\times
BRIDGE WORKSPACE	WORKSPACE TOOL	S VIEW	DESIGN/RATE	REPORTING			
a 🛤		∽ >>́	2 📙				
Analysis Analyze Analysi Settings Events							
Analysis	R	esults					

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**.

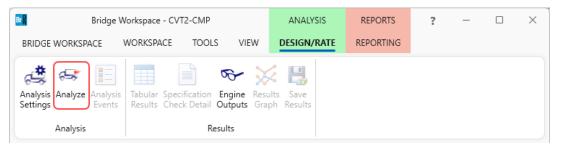
Templates	Description	Analysis	Owner	Public / Private	
HL 93 Design Review	HL 93 Design Review	LRFD		Public	
HS 20 LFR Rating	HS 20 LFR Rating	LFR		Public	
LRFR Design Load Rating	LRFR Design Load Rating	LRFR		Public	
LRFR Legal Load Rating	LRFR Legal Load Rating	LRFR		Public	

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

Design review Rating Analysis type: Line Girder Lane / Impact loading type: Analysis type: Line Girder Lane / Impact loading type: Analysis type: Lane / Impact loading type: Analysis type: Line Girder Apply preference setting: None Vehicles Output Engine Design review Analysis type: Line Girder Vehicles Output Engine Description Vehicle summary Vehicle summary Patternate Military Loading -EV3 +15.44 +12.0-44 +15.15-44 +15.20.41 -EV3 +15.15-44 +15.20.41 -EV3 +15.20.41 -EV3 +15.20.41 -EV3 -FX3 -FX4 +15.20.41 -EV3 -FX4 +15.20.41 -EV3 -FX4 -FX3 -FY8.20.41 -FY8.20.41 </th <th>Analysis Settings</th> <th></th> <th></th> <th>_</th> <th>></th>	Analysis Settings			_	>
Lane / Impact loading type: As Requested Apply preference setting: None Vehicles Output Engine Description Traffic direction: Both directions Vehicles Ve	Design review O Rating	Rating method:	LFR	~	
Vehicles Output Engine Description Traffic direction: Both directions	Analysis type: Line Girder 🗸				
Traffic direction: Both directions Refresh Temporary vehicles Vehicle selection Vehicle summary Image: Standard -Alternate Military Loading Image: Standard Image: Standard Image: Standard Image: Standard <	ane / Impact loading type: As Requested V	Apply preference setting	None	~	
Vehicle selection Vehicle summary Uehicle selection Vehicle summary Uehicle summary Uehi	Vehicles Output Engine Description				
 ➡ Vehicles ➡ Standard → Alternate Military Loading ← EV2 ← EV3 ← H 15-44 ← H 20-44 ← H 20-44	Traffic direction: Both directions	Refresh	Temporary vehicles	Advanced	
 Standard Alternate Military Loading EV2 EV3 H 15-44 H 20-44 HS 15-44 HS 20 (SI) HS 20 (SI) HS 20-44 -Legal operating -Permit inventory -Permit operating -Permit ope			-		
• lemporary	Alternate Military Loading EV2 EV3 H 15-44 H 20-44 HS 15-44 HS 20 (SI) HS 20-44 NRL SU4 SU5 SU5 SU6 SU7 Type 3 Type 3-3 Type 3S2 Agency	Add to Add to Remove from	ny 20-44 ing 20-44 perating inventory		

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.

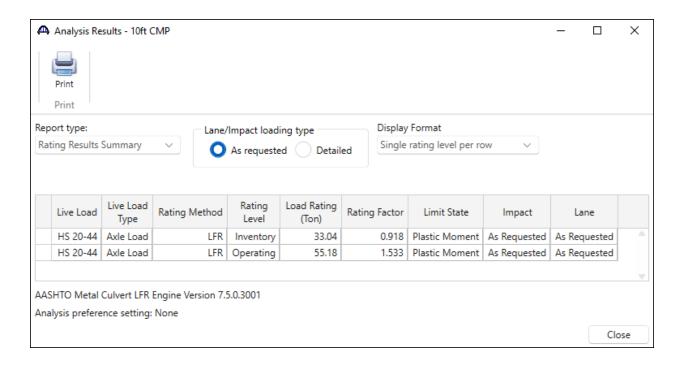


Tabular Results

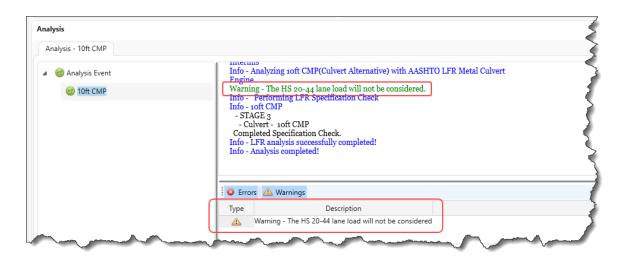
When the rating is completed, results can be reviewed by clicking the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon.



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.

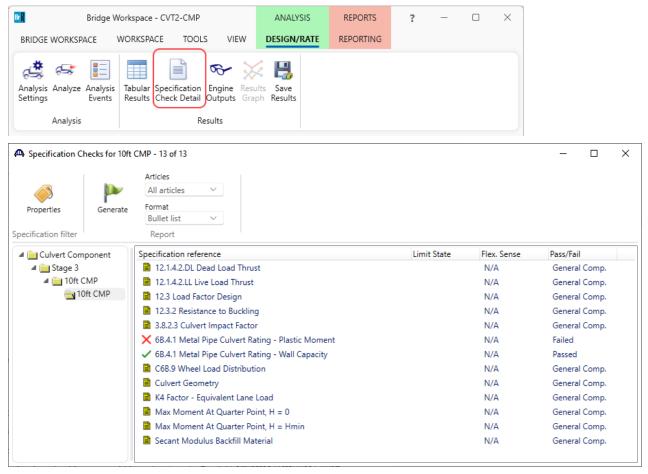


Review the **Analysis Progress** log shown below. The warning shown informs that the lane load portion of the HS 20-44 vehicle is not considered for the metal culvert analysis. Some advanced vehicle loading options are not applicable to the metal culvert analysis including lane loads, adjacent vehicles,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

```
📴 Spec Check Detail for C6B.9 Wheel Load Distribution
                                                                                                 Х
                                                                                                         .
 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 1w Pressure
        (kip) (ft)
                                   (ft) (kip/ft)
                 8.00 --- 0.83 1.85
32.00 14.00 0.83 7.38
32.00 14.00 0.83 7.38
  1
  2
  3
 WD Wheel = wt + LLDF * H
 WD Axle = Min(WD Wheel * 2, wt + sw + LLDF * H)
               Total
                          Axle
           Axle Load Spacing
  Axle No.
                                    WT.
                                                  WD Wheel
                                                             WD Axle
                                             SW
               (kip)
                          (ft)
                                    (ft)
                                            (ft)
                                                  (ft)
                                                              (ft)
 2
             32.00 --- 1.67 6.00 5.17 10.33
 Single Lane Results:
 Live load patch length at depth (lw) = 22.39 (ft<sup>2</sup>)
Total live load for all free
 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)
                                                                        Live Load Live Load
                              --- 5.17 16.00 22.39 0.86
1.33 19.17 32.00 40.42 0.95
       1.00
1.00
  1
  2
                                      _____
                                                                                                    OK
```

Corrugated Metal Pipe Culvert LRFR Analysis.

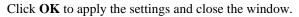
LRFR Analysis

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**.

Templates	Description	Analysis	Owner	Public / Private	
HL 93 Design Review	HL 93 Design Review	LRFD		Public	
HS 20 LFR Rating	HS 20 LFR Rating	LFR		Public	
LRFR Design Load Rating	LRFR Design Load Rating	LRFR		Public	
LRFR Legal Load Rating	LRFR Legal Load Rating	LRFR		Public	

The Analysis Settings window will be populated as shown below.

Design review O Rating	Rating method:	LRFR	~	
nalysis type: Line Girder V				
ane / Impact loading type: As Requested V	Apply preference setting	: None	~	
Vehicles Output Engine Description				
Traffic direction: Both directions \checkmark	Refresh	Temporary vehicles	Advanced	
Vehicle selection	Vehicle summa	ry		
 Standard -EV3 -H 15-44 -H 20-44 -HL-93 (SI) -HL-93 (US) -HS 15-44 -HS 20 (SI) -HS 20 - 44 -Lane-Type Legal Load -LRPD Fatigue Truck (SI) -LRPD Fatigue Truck (US) -NRL -SU4 -SU5 -SU4 -SU7 -Type 3 -Type 3S2 -Agency -User defined Temporary 	Add to	ign load rating Inventory 'HL-93 (US) Operating 'HL-93 (US) Fatigue 'IL-P6 Fatigue Truck (US) Ial load rating Routine Type 3 Type 3 Type 3 2 Type 3-3 Type 4 		



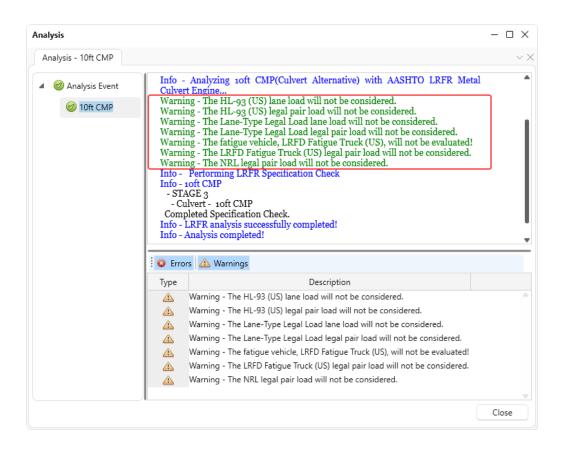
Click **Analyze** on the ribbon to launch the rating. When the rating analysis is complete, review the results by clicking the **Tabular Results** button on the ribbon.

Bridge W	/orkspace - CVT2-CMP	ANALYSIS	REPORTS	?	_	\times
BRIDGE WORKSPACE	WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING			
Analysis Analyze Analysis Settings	Tabular Specification Engine Results Check Detail Outputs Gra					
Analysis	Results					

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.

P	Analysis Results - 10ft C Print Print	MP								×
Repor	rt type:		Lane/Impact load	ing type	Dis	play Format				
Ratin	g Results Summary	\sim	As requeste		ailed	gle rating level	per row 🗸			
	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	
l	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	
		Axle Load	LRFR	Legal	45.10	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested	
	Type 3				76.66	1.917	STRENGTH-I Plastic Moment	As Requested	As Requested	
	Туре 3 Туре 3-3	Axle Load	LRFR	Legal	70.00					

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.

Properties	Genera	IOft CMP - 13 of 13 Articles All articles Format Bullet list Report Report			- 0	×
4 🛅 Culvert Com	ponent	Specification reference	Limit State	Flex. Sense	Pass/Fail	
🔺 🚞 Stage 3		12.7.2 Safety Against Structural Failure		N/A	General Comp.	
▲ i 10ft CMP ■ 10ft CMP		12.7.2.2.DL Dead Load Thrust		N/A	General Comp.	
		12.7.2.2.LL Live Load Thrust		N/A	General Comp.	
		12.7.2.4 Resistance to Buckling		N/A	General Comp.	
		3.6.2.2 Culvert Dynamic Load Allowance		N/A	General Comp.	
		6A.10.10.3a Wheel Load Distribution		N/A	General Comp.	
		✓ 6A.10.4 Culvert Load Rating Equation - Duncan and Drawsky Plast	ic M	N/A	Passed	
		✓ 6A.10.4 Culvert Load Rating Equation - Wall Capacity		N/A	Passed	
		Culvert Geometry		N/A	General Comp.	
		K4 Factor - Equivalent Lane Load		N/A	General Comp.	
		Max Moment At Quarter Point, H = 0		N/A	General Comp.	.p.
		Max Moment At Quarter Point, H = Hmin		N/A	General Comp.	
		Secant Modulus Backfill Material		N/A	General Comp.	

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.

Spec Check D	etail for 6A.10.10	.3a Wheel Load	Distributio	on				-		>
Wehicle: HL	-93 (US) - T:	ruck - Desig	gnOp - S							
lire Patch	Length (lt) =	= 10.00 (in	n) for H	L-93 loa	ding					
heel Load	Distribution	to Critical	l Axle G	roup						
	th of Fill (B			2.00 (f 10.00 (f						
a-crit = H	*LLDF + lt		=	3.13 (f	it)					
Axle No.	Total Axle Load (kip)	Spacing 1	Pressure (kip/ft)							
1 2 3		14.00 14.00								
Axle No.	Total Axle Load (kip)	Spacing	wt (ft)	sw (ft)	Ww (ft)					
2	32.00		1.67	6.00	4.57					
ingle Lane	Results:									
otal area ive load p otal live	at depth H (A atch length a load for all	A_LL) at depth (lu interacting	w) g wheels	= = (P) =	14.31 3.13 16.00	(ft^2) (ft) (kip)				
ive Load V	ertical Crow	n Pressure	(P1) = -	P * (1 +	· IM / 10	00) * MPF	(3.6.1.2	(6b-7)		
			(,		A_LL		(
No. Lanes	MPF For In	nteraction (ft)	At D (f	epth t)	Intera	l From All ting Wheels (kip)	Area (ft^2)	Pressure (ksf)		
1	1.20			4.57		16.00				
									C	ОK