OHIO DEPARTMENT OF TRANSPORTATION

MIKE DEWINE, GOVERNOR

JACK MARCHBANKS, DIRECTOR

Metal Culvert Rating

Amjad Waheed, PE

OHDOT

RADBUG 2023, Madison WI

2023

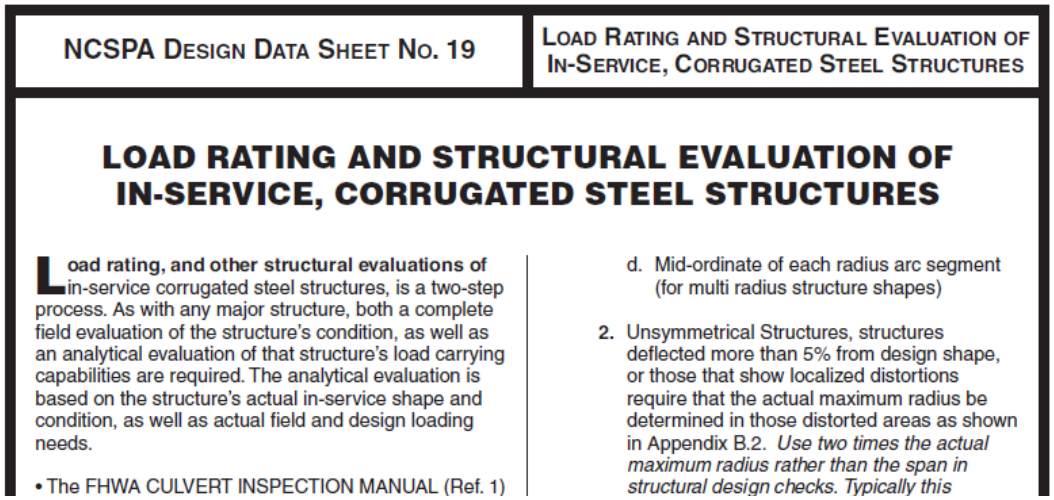
Referenced Specifications

1. ASHTO Standard Specifications for Highway Bridges-Division 1, Section 12
2. AASHTO LRFD Bridge Design Specifications – Section 12
3. ASTM Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications – ASTM A796
4. AREMA Manual for Railway Engineering – Section 4.9

On-line Resources

- www.transportation.org
- www.astm.org
- www.NCSPA.org
  - NCSPA Corrugated Steel Pipe Design Manual
  - Design Data Sheet #19 – “Load Rating and Structural Evaluation of In-Service, Corrugated Steel Structures”

On-line Resources



NCSPA DESIGN DATA SHEET NO. 19 | LOAD RATING AND STRUCTURAL EVALUATION OF IN-SERVICE, CORRUGATED STEEL STRUCTURES

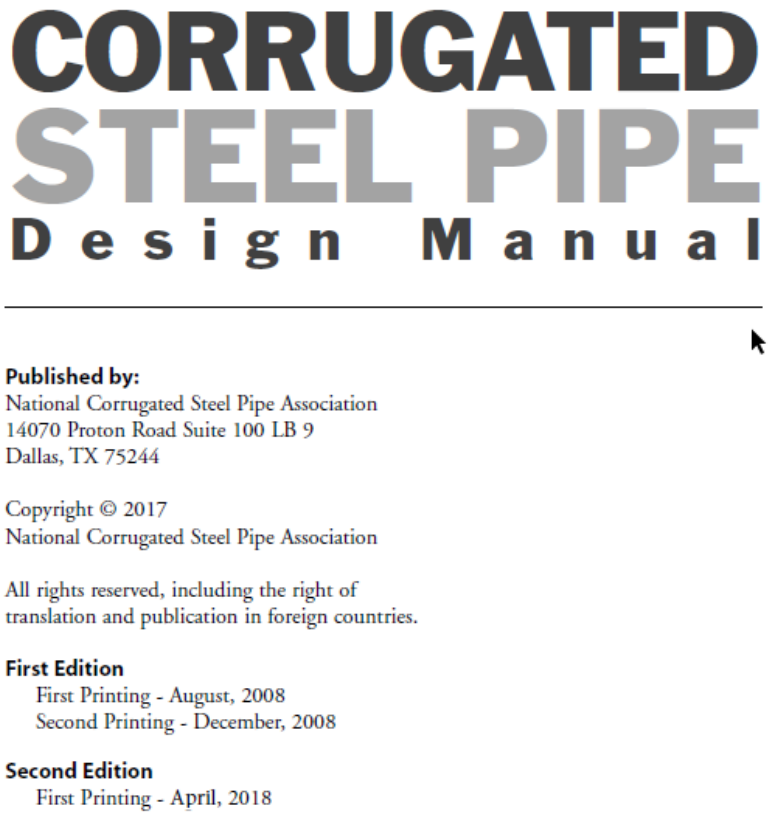
LOAD RATING AND STRUCTURAL EVALUATION OF IN-SERVICE, CORRUGATED STEEL STRUCTURES

Load rating, and other structural evaluations of in-service corrugated steel structures, is a two-step process. As with any major structure, both a complete field evaluation of the structure's condition, as well as an analytical evaluation of that structure's load carrying capabilities are required. The analytical evaluation is based on the structure's actual in-service shape and condition, as well as actual field and design loading needs.

• The FHWA CULVERT INSPECTION MANUAL (Ref. 1)

d. Mid-ordinate of each radius arc segment (for multi radius structure shapes)

2. Unsymmetrical Structures, structures deflected more than 5% from design shape, or those that show localized distortions require that the actual maximum radius be determined in those distorted areas as shown in Appendix B.2. *Use two times the actual maximum radius rather than the span in structural design checks. Typically this*



CORRUGATED STEEL PIPE Design Manual

Published by:
National Corrugated Steel Pipe Association
14070 Proton Road Suite 100 LB 9
Dallas, TX 75244

First Edition
First Printing - August, 2008
Second Printing - December, 2008

Second Edition
First Printing - April, 2018

STEEL

NCSPA
National Corrugated Steel Pipe Association

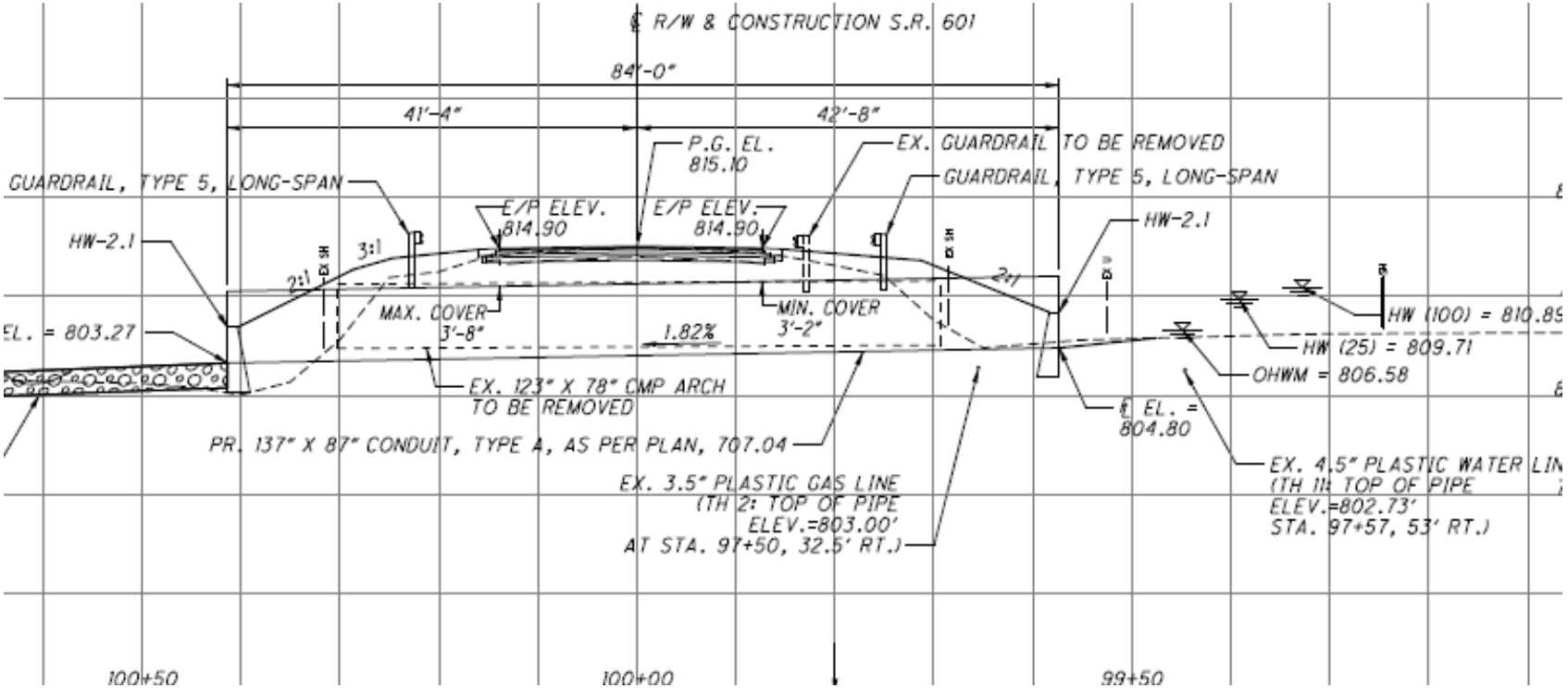
CMP (Corrugated Metal Pipe)

Metal Culvert Rating in BrR 7.4.1

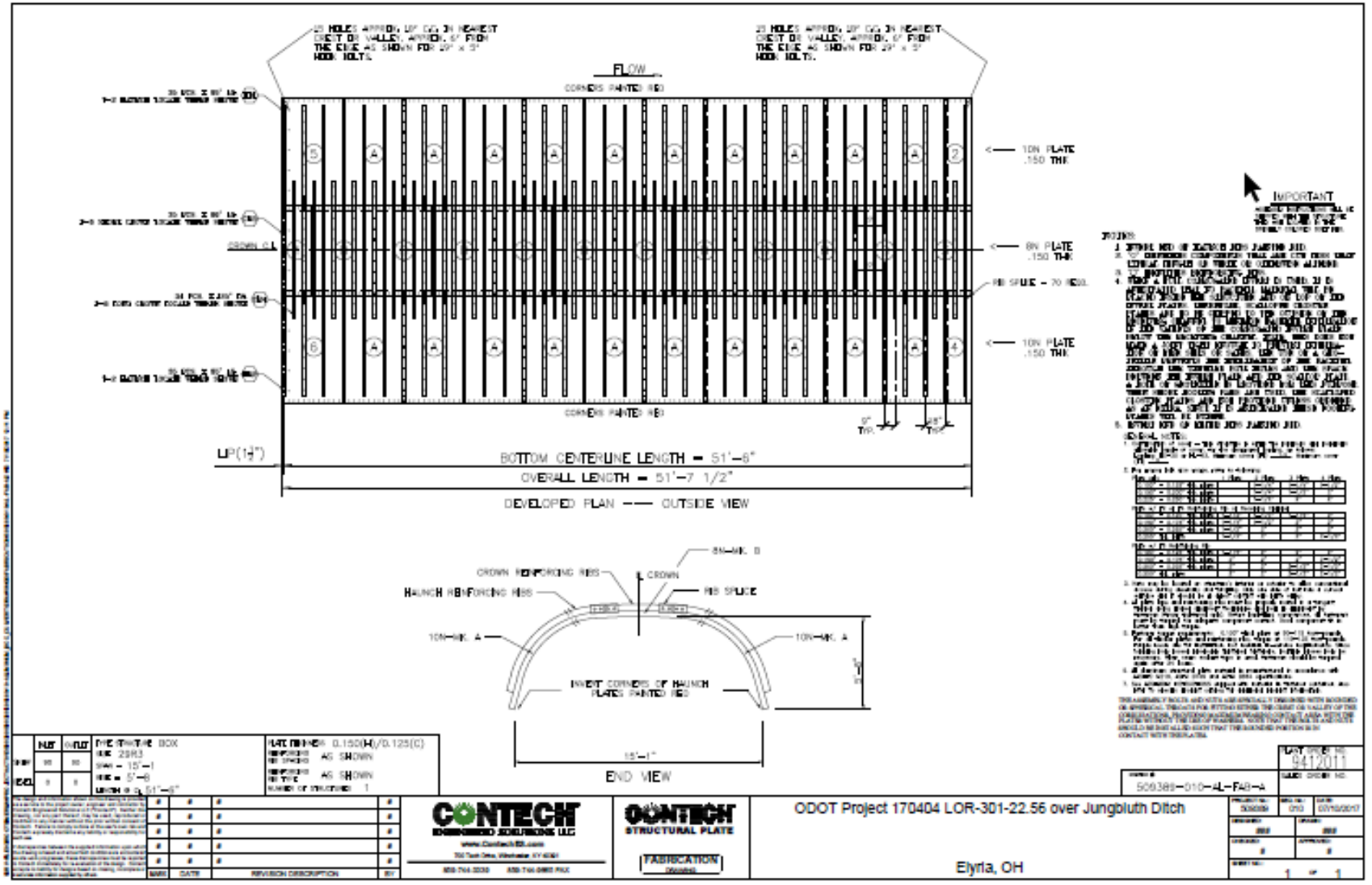
Metal Box Culvert

Metal Culvert Rating in BrR 7.4.1

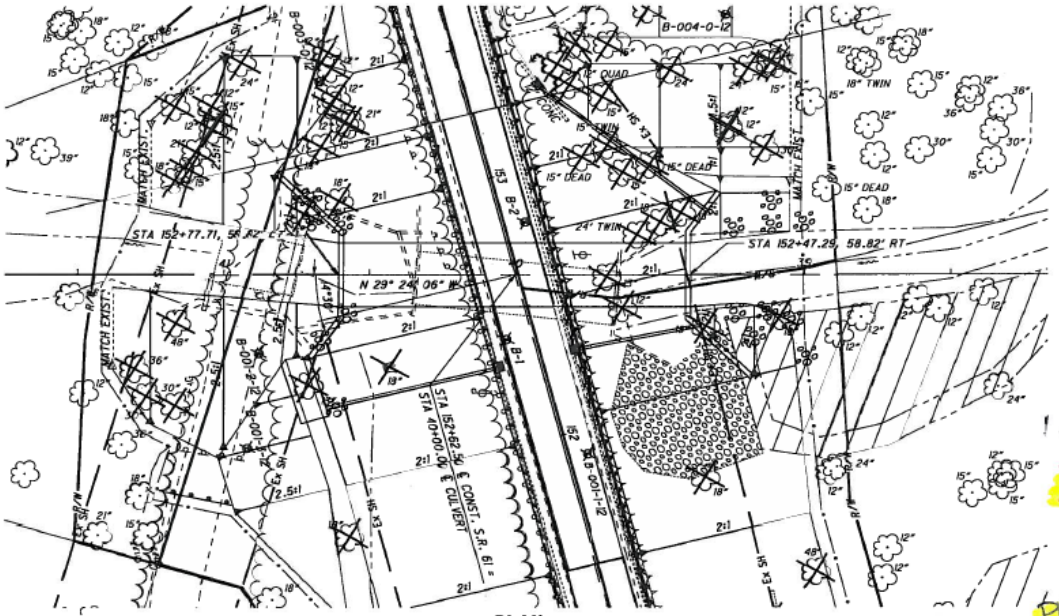
Example of a CMP

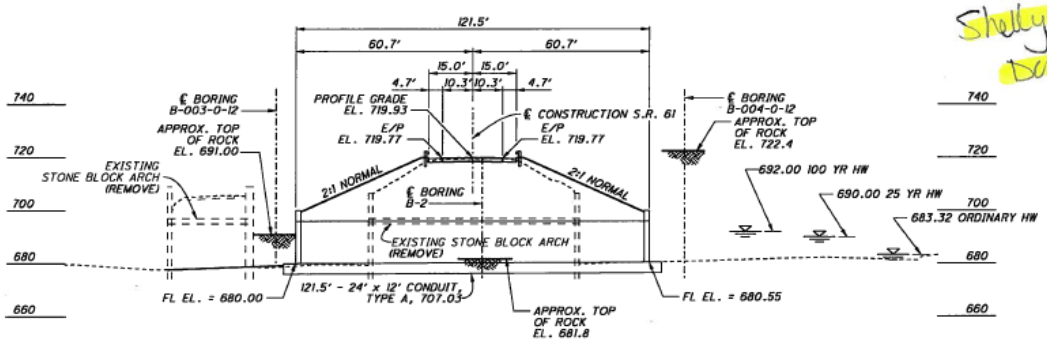


Shop Drawings



Metal Culvert Rating in BrR 7.4.1





PROFILE ALONG CENTERLINE CULVERT

BENCHMARK DATA

BENCHMARK NO. 4:
BERNSTEN MARKER LABELED SURVEY CONTROL
STA. 151+05.31, 166.41' LT.
ELEV. 708.42

BENCHMARK DATA

BENCHMARK NO. 10:
BERNSTEN MARKER LABELED SURVEY CONTROL
STA. 152+75.55, 87.68' LT.
ELEV. 705.70

LEGEND
BORING LOCATION
ROCK CHANNEL PROTECTION

HYDRAULIC DATA
DRAINAGE AREA = 7.58 SQUARE MILES
Q (25) = 1370 CFS V (25) = 9.70 FT/S
Q (100) = 1840 CFS V (100) = 11.32 FT/S

BORING	STATION	OFFSET	TOP OF GROUND ELEVATION
B-001-1-12	151+91	7.5 RT.	719.4
B-001-2-12	152+56	92.6 LT.	704.8
B-001-3-12	152+22	105.2 LT.	702.9
B-003-0-12	153+50	47.1 LT.	710.1
B-004-0-12	153+39	95.2 RT.	732.4
B-1	152+36	9.1 LT.	720.3
B-2	152+78	8.1 RT.	720.2

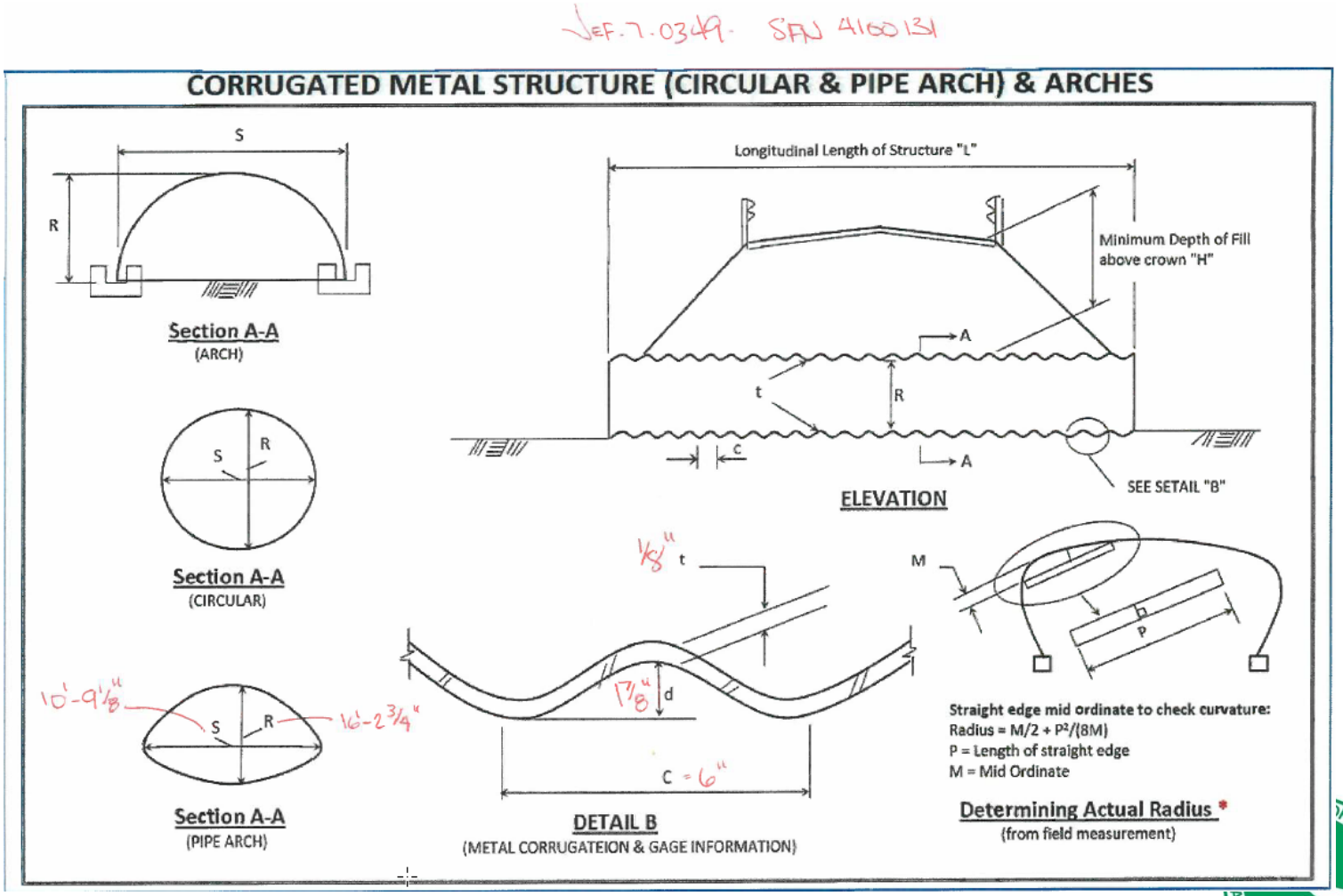
EXISTING STRUCTURE
TYPE: STONE BLOCK SPANDREL ARCH
SPAN: ±20'-0"
ROADWAY: ±31'-0" F/F RAIL
LOADING: UNKNOWN
SKEW: 21°-0"± L.F.
APPROACH SLABS: NONE
ALIGNMENT: TANGENT
CROWN: 0.016±
STRUCTURAL FILE NUMBER: 3902102
DATE BUILT: 1930

PROPOSED STRUCTURE
TYPE: STRUCTURAL STEEL PLATE ARCH ON REINFORCED CONCRETE SPREAD FOOTING
SPAN: 24'-0"
ROADWAY: 28'-0" F/F RAIL
LOADING: HL-93
SKEW: 14°30'00" L.F.
APPROACH SLABS: NONE
ALIGNMENT: TANGENT
CROWN: 0.016 FT/FT
COORDINATES: LATITUDE N41°16'13"
LONGITUDE W82°34'16"

Proj. 377-13
Shelly/Sando
Donofrio

Metal Culvert Rating in BrR 7.4.1

Example of field measurements



Metal Culvert Rating in BrR 7.4.1

Example of field measurements

Wang, Cindy

From: Wisse, Geoffry
Sent: Tuesday, October 5, 2021 2:32 PM
To: Wang, Cindy; Waheed, Amjad
Cc: Eilerman, Lee
Subject: RE: Load Rating

Follow Up Flag: Follow up
Flag Status: Flagged

Cindy,
Span = 9.5'. 27 degree skew = 10.7' along center line
Rise = 6.5'
Metal Corrugation = C= 6", d= 2"
Guage/thickness = 0.158"
Depth of fill = 4'
Radius = I don't know.

Geoff Wisse

From: Wang, Cindy <Cindy.Wang@dot.ohio.gov>
Sent: Tuesday, October 5, 2021 10:11 AM
To: Waheed, Amjad <Amjad.Waheed@dot.ohio.gov>; Wisse, Geoffry <Geoff.Wisse@dot.ohio.gov>
Subject: RE: Load Rating

Geoff,
I need little more information regarding the load rating of this CMP. Can you send someone to the field and do some measurements? I need the span, rise, radius and metal corrugation, gage information, and depth of fill information.

Metal Culvert Rating in BrR 7.4.1

Metal Culvert Rating in BrR 7.4.1

Load Rating of CMP

Load Factor Rating
Basic AASHTO Equation

Operating rating factor

$$RFo = \frac{S}{1.3} - \beta * D / (L + I)$$

S = Strength

D = Dead load effect

L = Live Load effect

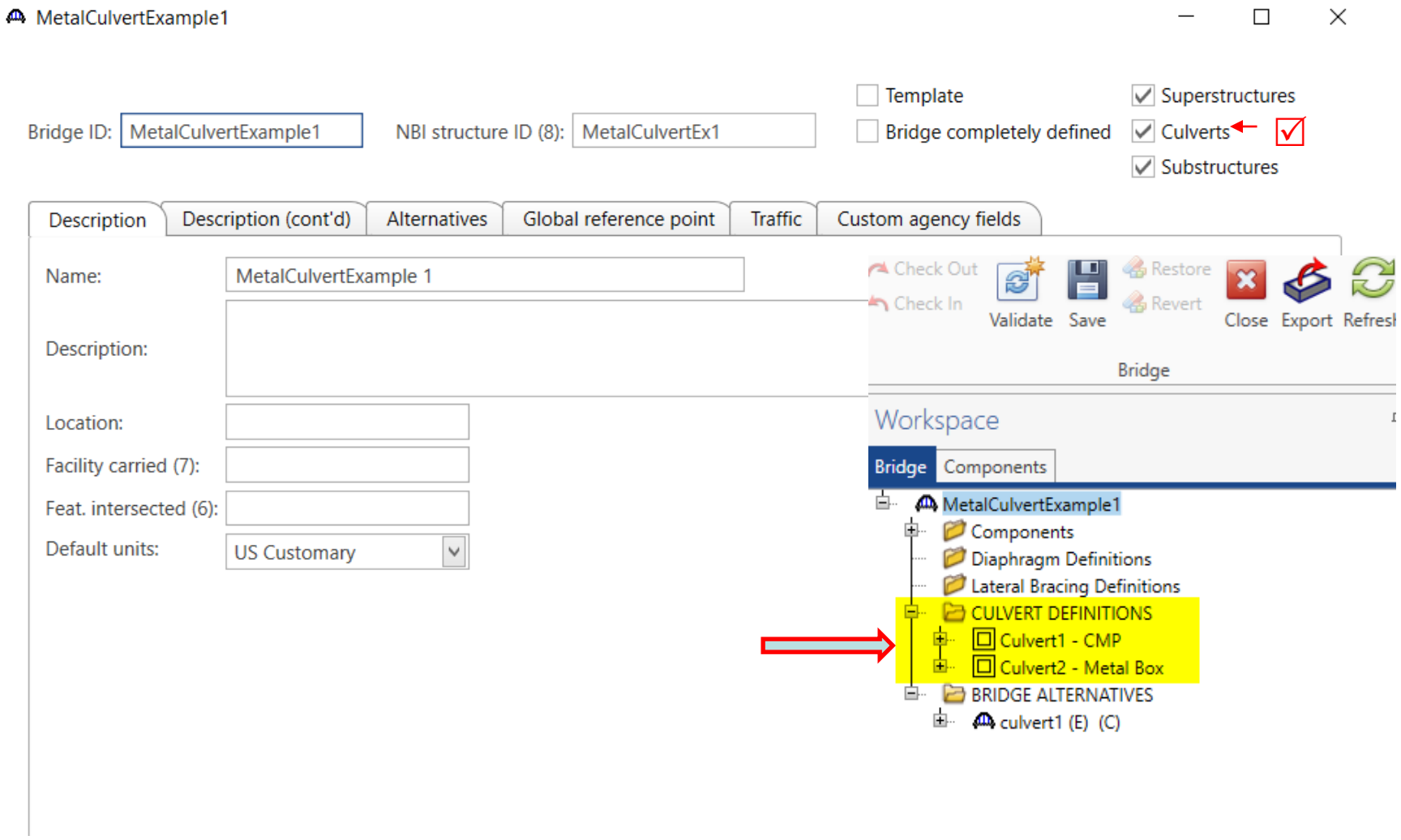
I = Dynamic effect

β = Dead load factor

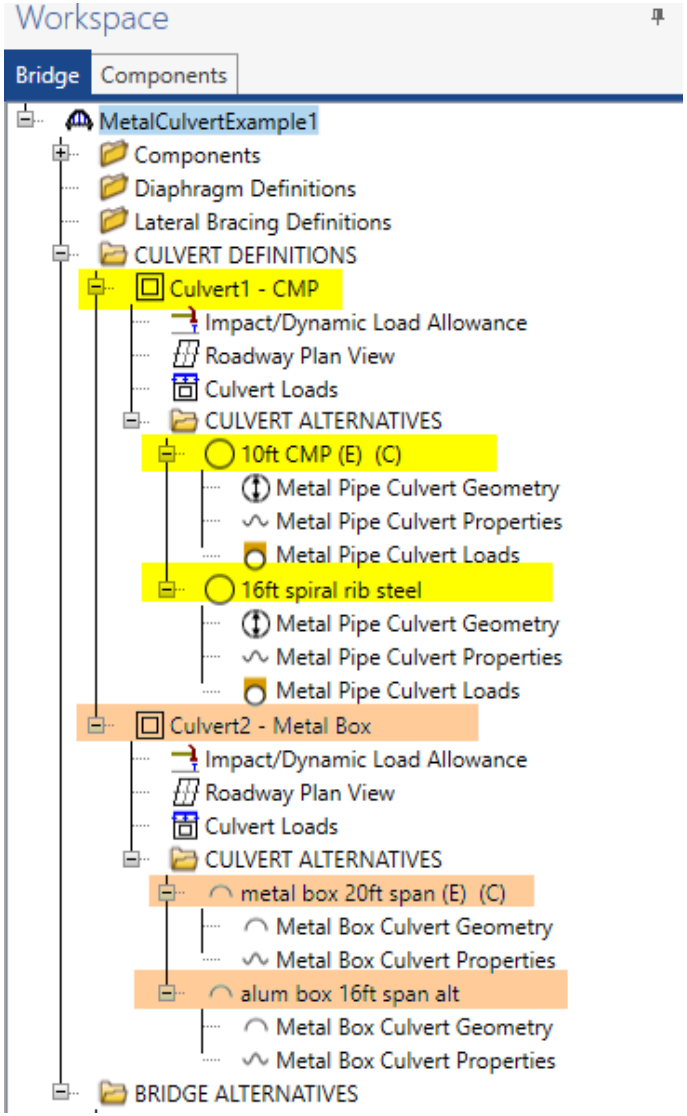
Inventory rating factor (RFi) = $\frac{3}{5}$ *RFo

Metal Culvert Example 1
BrR 7.4.1

Metal Culvert Rating in BrR 7.4.1

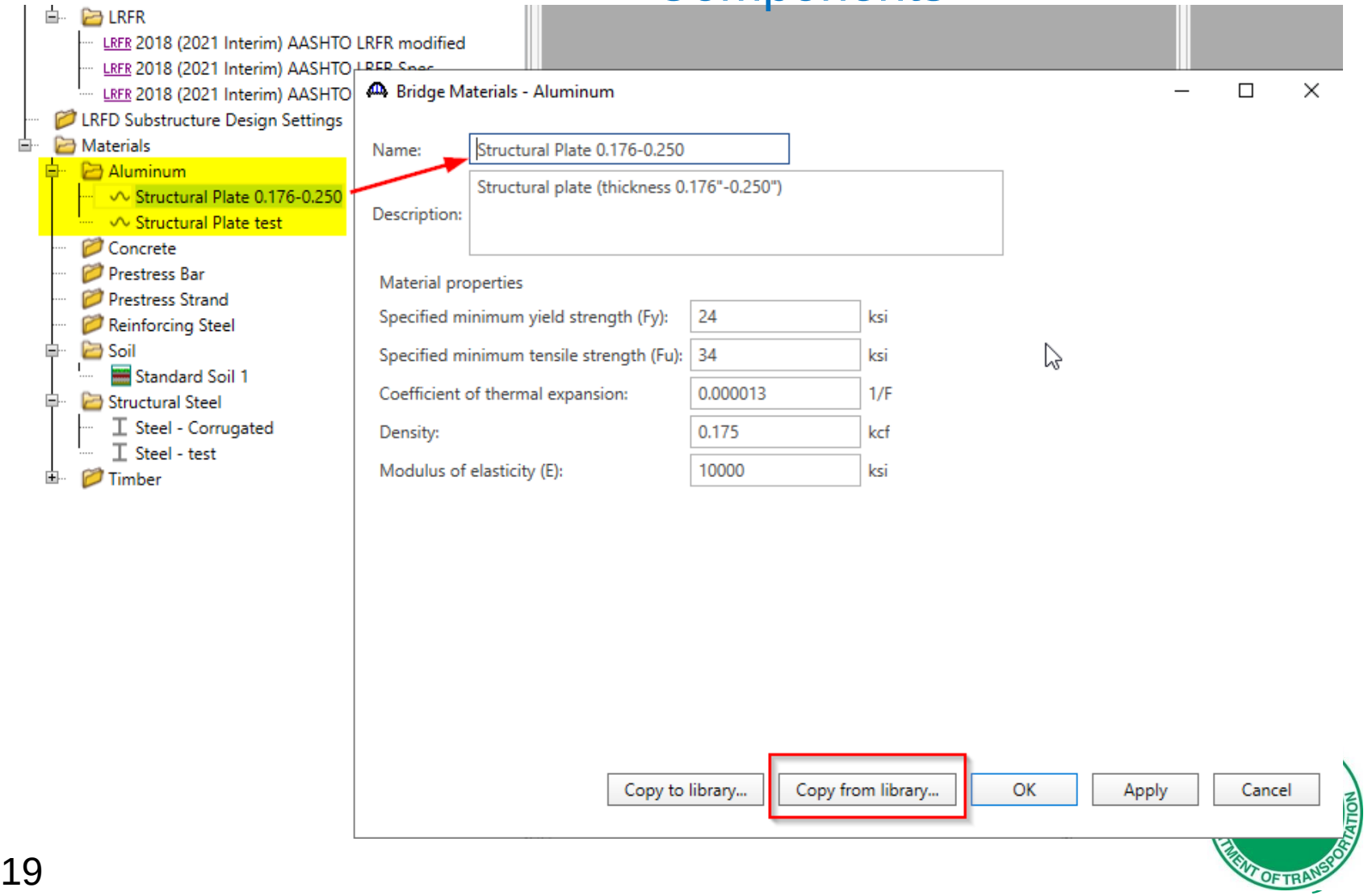


Metal Culvert Rating in BrR 7.4.1

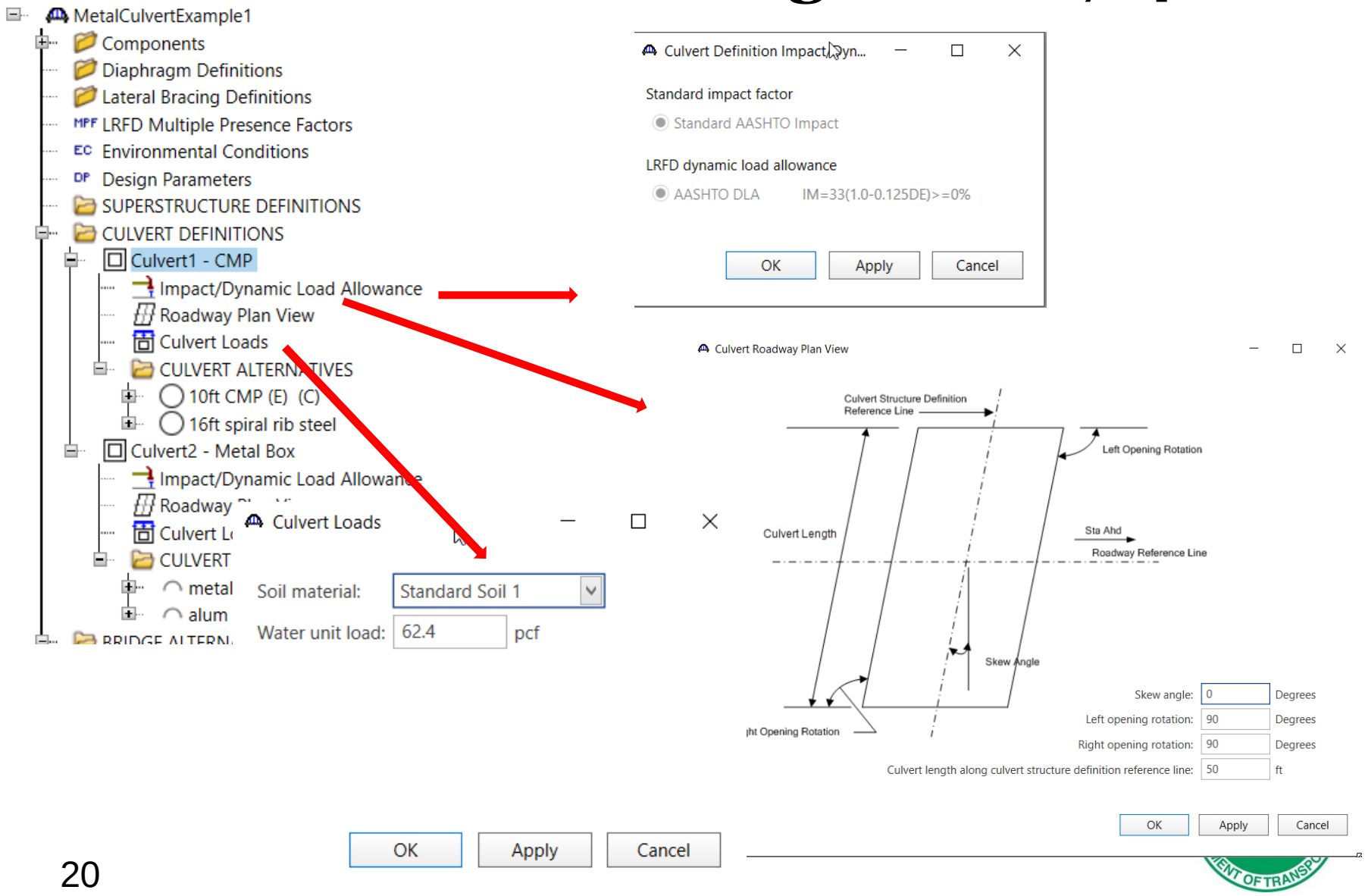


Metal Culvert Rating in BrR 7.4.1

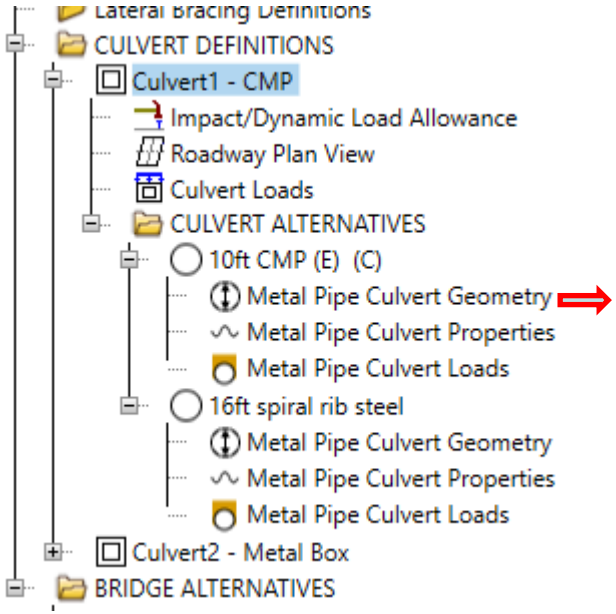
Components

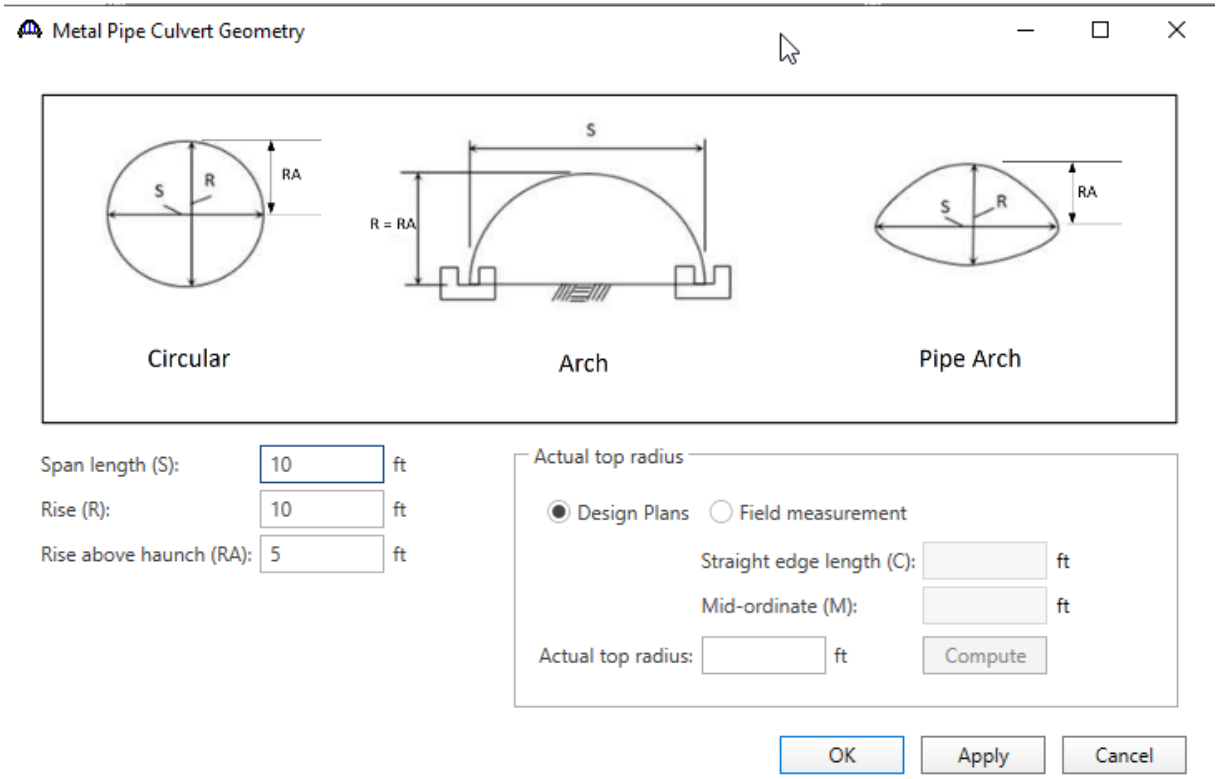


Metal Culvert Rating in BrR 7.4.1



Metal Culvert Rating in BrR 7.4.1





Metal Culvert Rating in BrR 7.4.1

Field measurements

Check this option to enter field measurement values. Checking this box enables the options below and the compute button:

Straight edge length (C)

Enter the straight edge length for the metal pipe culvert.

Mid-ordinate (M)

Enter the Mid-ordinate value for the metal pipe culvert.

Actual top radius

Enter the top radius of the metal pipe culvert or use the Compute button to calculate the actual top radius based on the formula shown below. This value is required if the structure category type is Long Span, Unsymmetrical or Deflect over 5%. This value must be entered.

Compute

Computes the actual top radius of the metal pipe culvert based on the following equation:

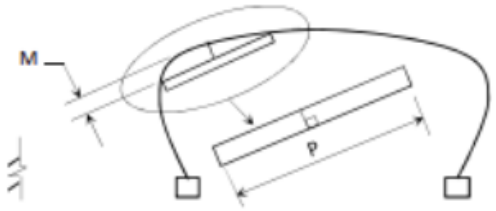
$$R = \frac{M}{2} + \frac{C^2}{8M}$$

Where,

R = actual top radius

M = Mid-ordinate

C = Straight edge length (C)



Straight edge mid ordinate to check curvature:

Radius = $M/2 + P^2/(8M)$

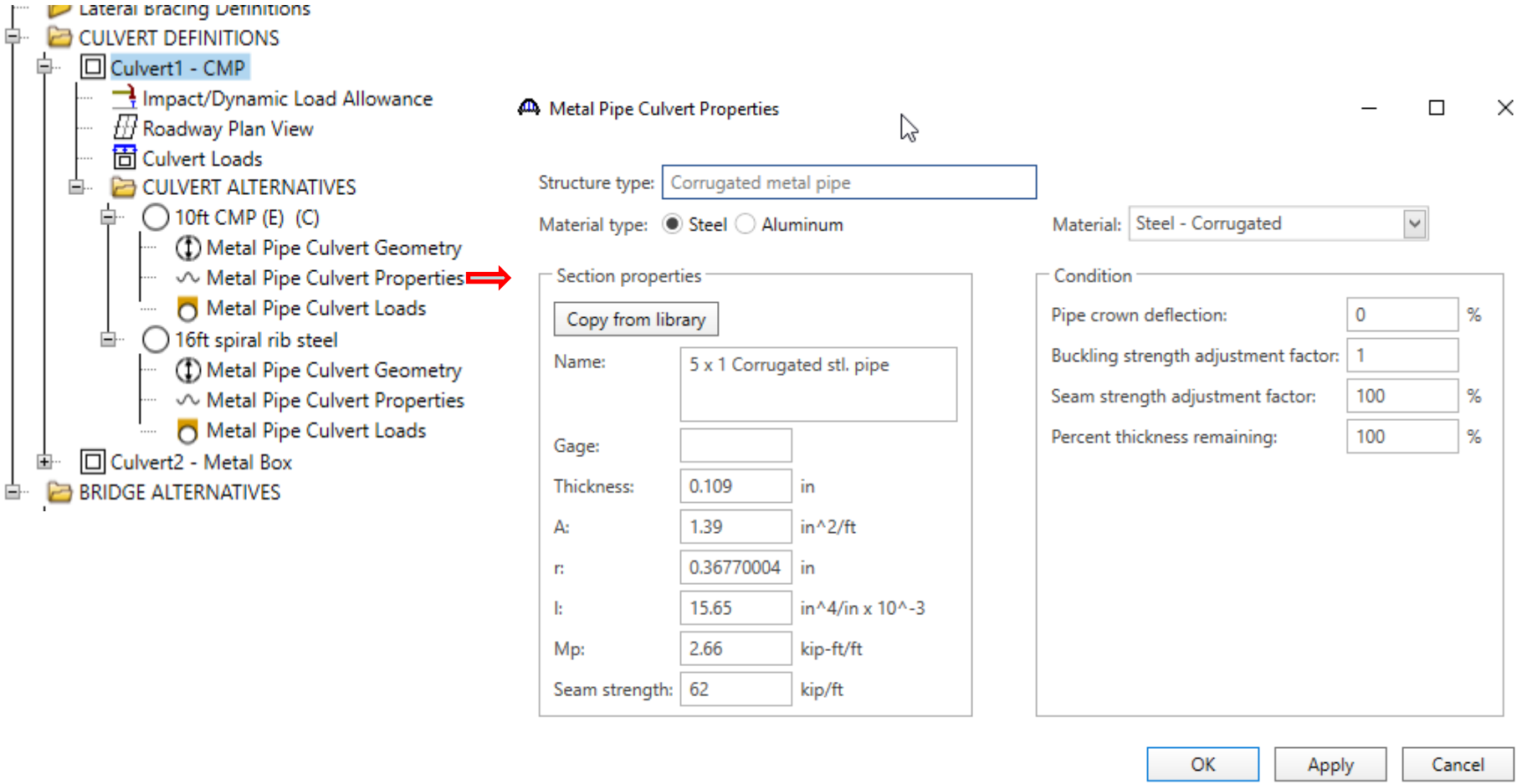
P = Length of straight edge

M = Mid Ordinate

Determining Actual Radius

(from field measurement)

Metal Culvert Rating in BrR 7.4.1



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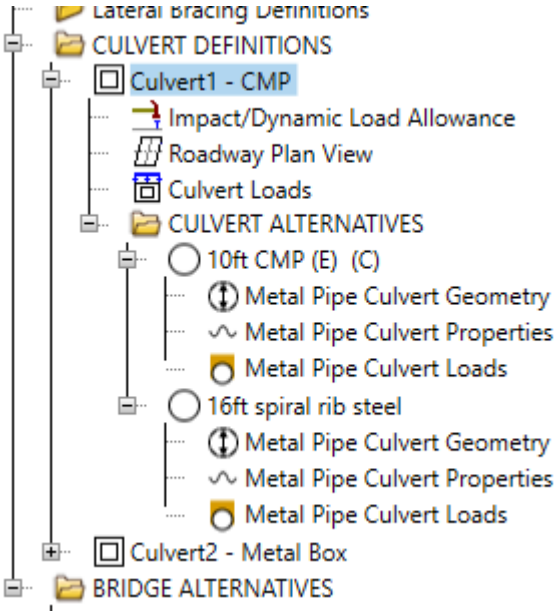
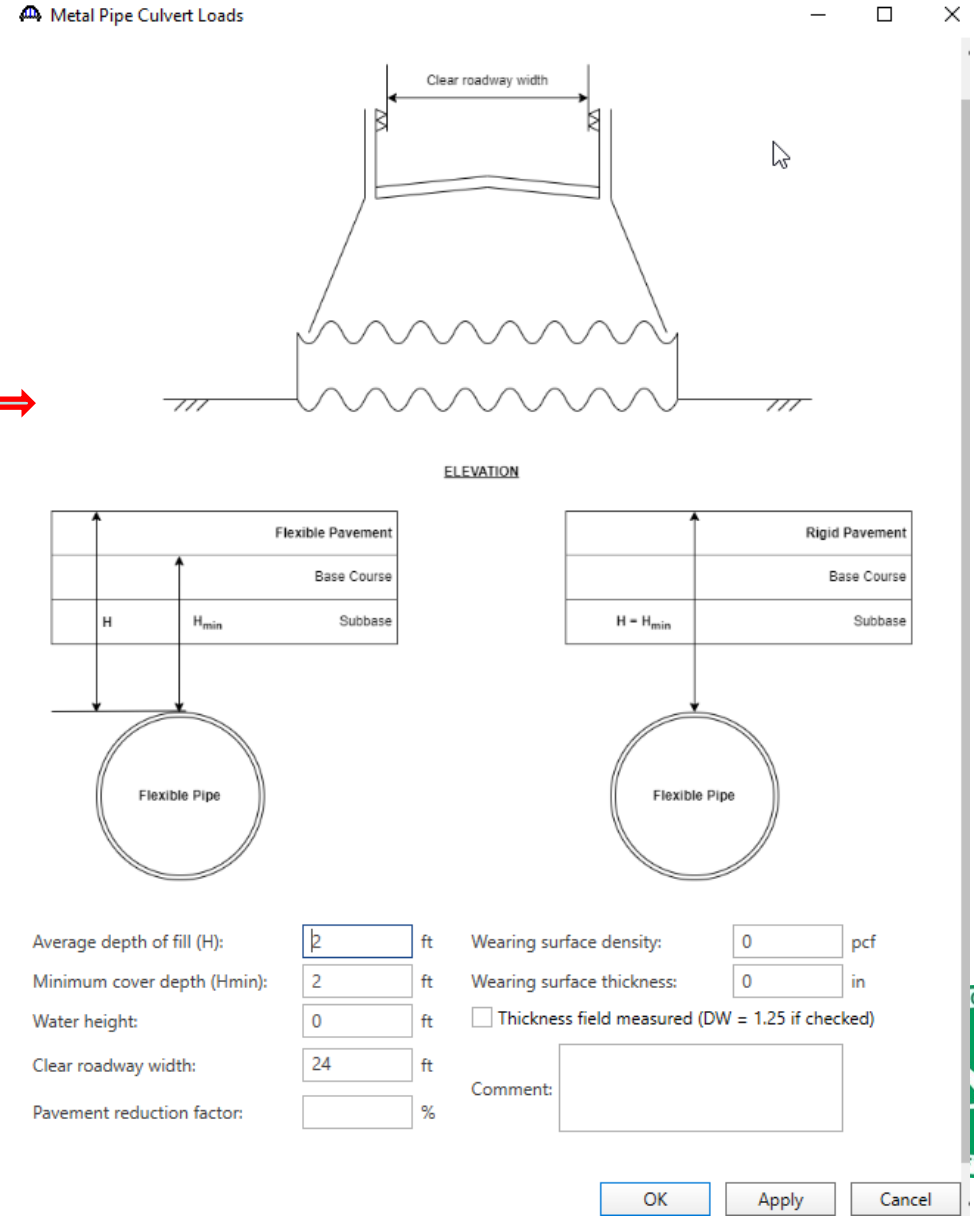
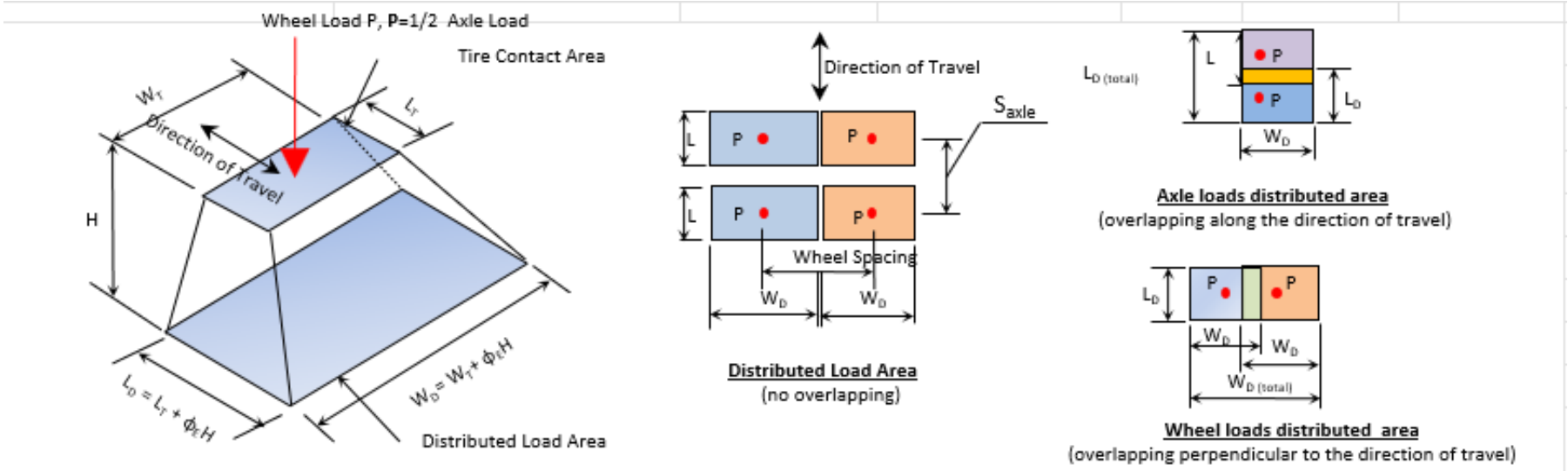




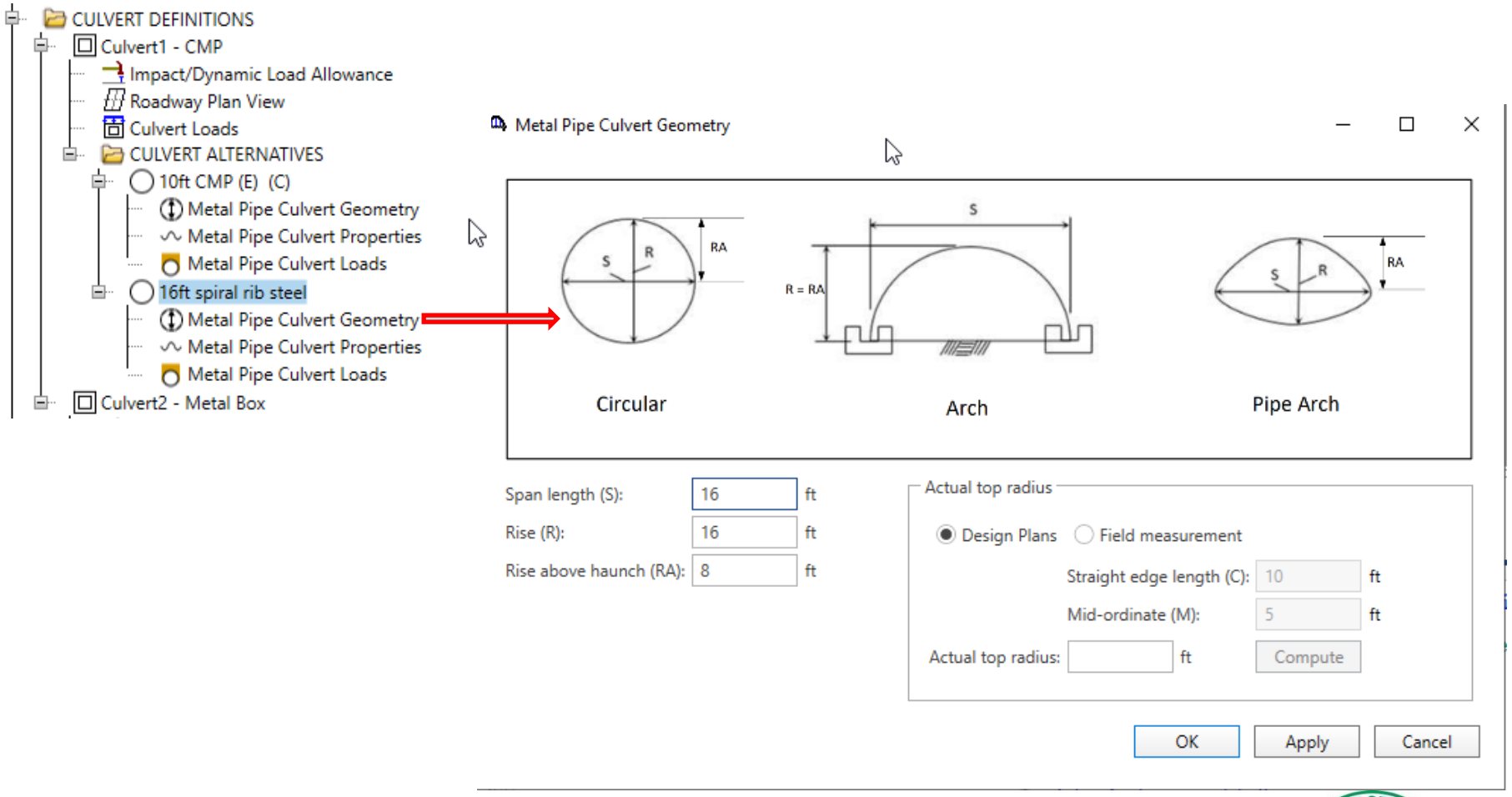
Load Rating of CMP

Wheel Load distribution through fill



Where, W_T = Tire contact width, L_T = Tire contact length, W_D = Distributed load width, L_D = Distributed load length

Metal Culvert Rating in BrR 7.4.1



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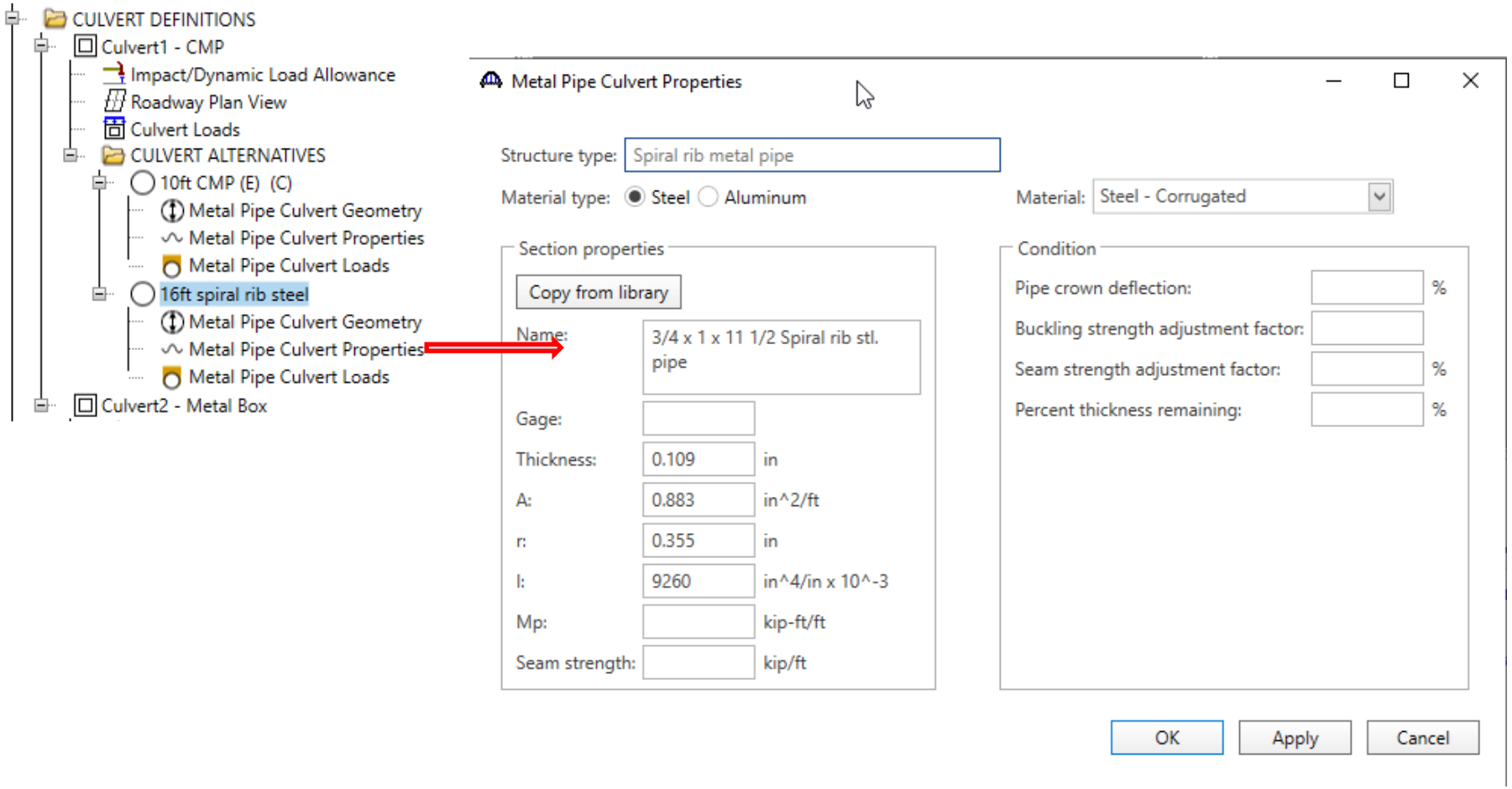

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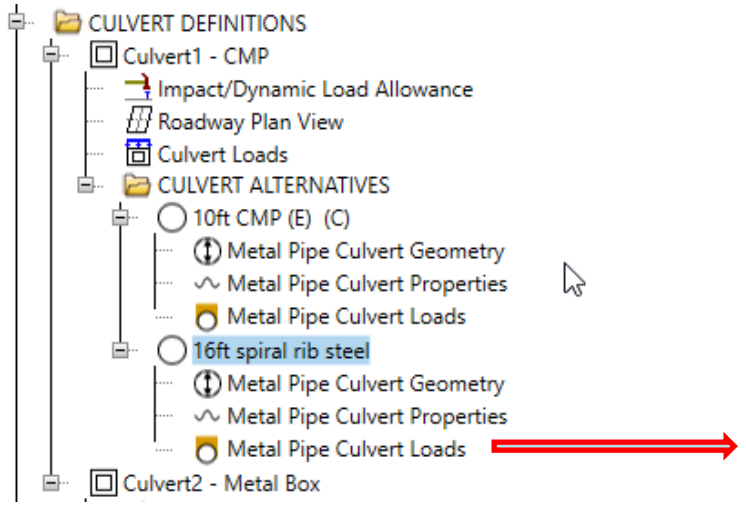

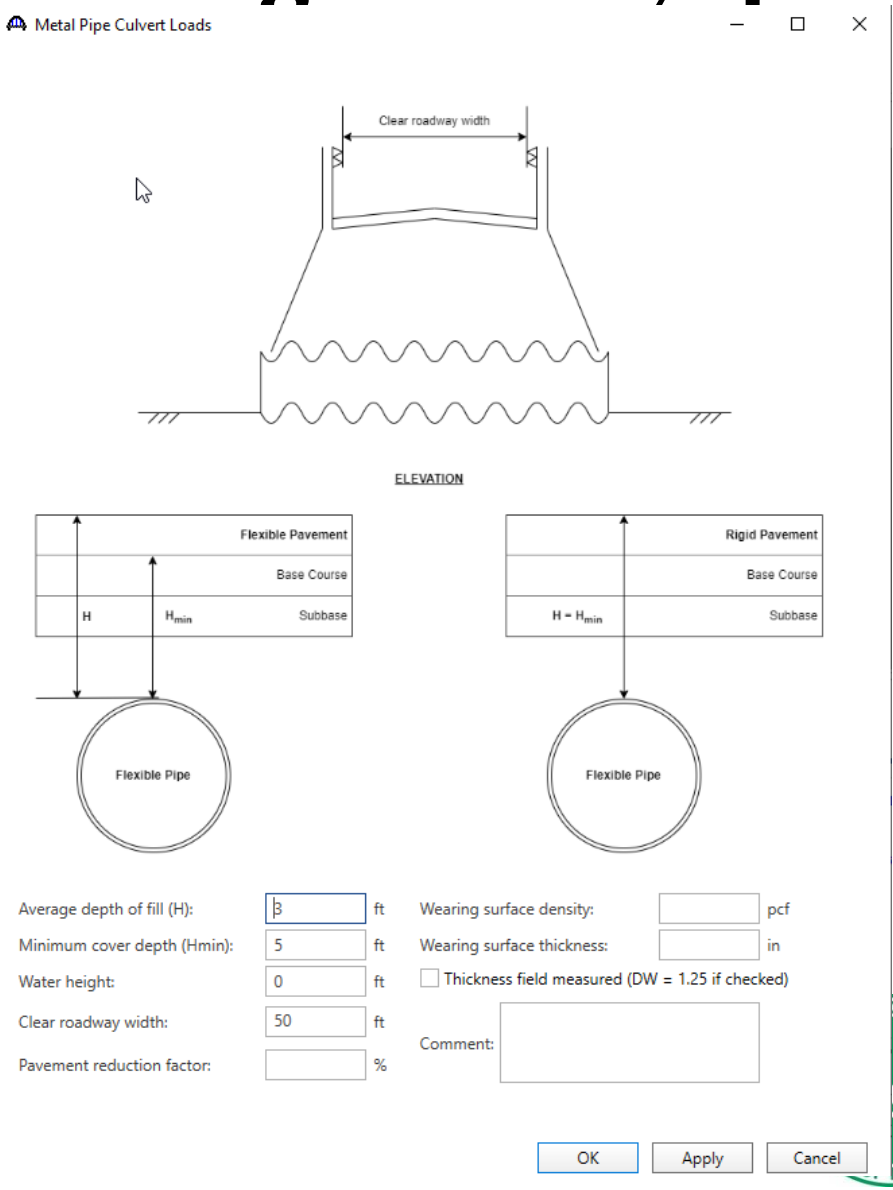

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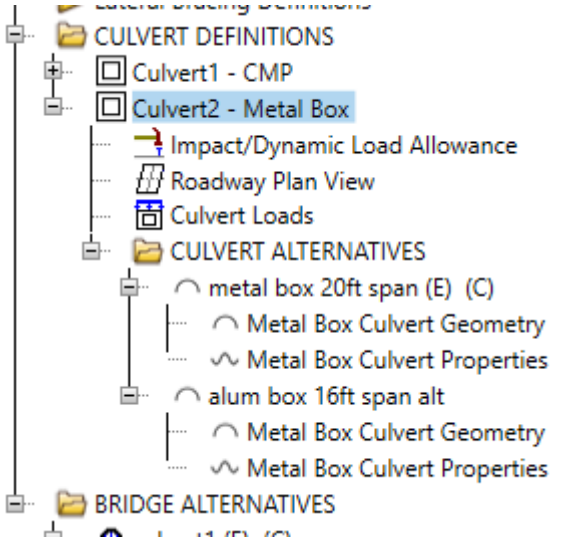

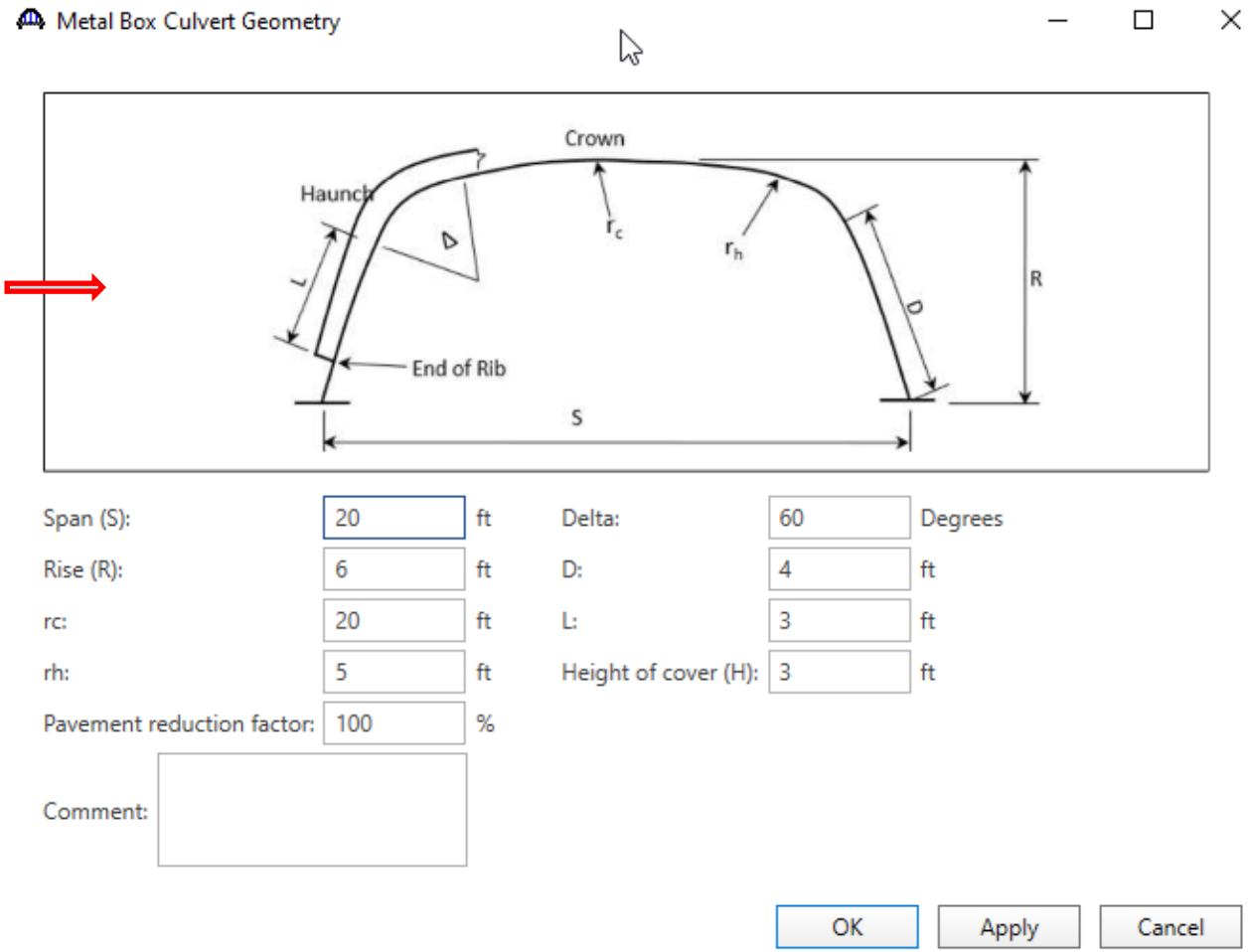

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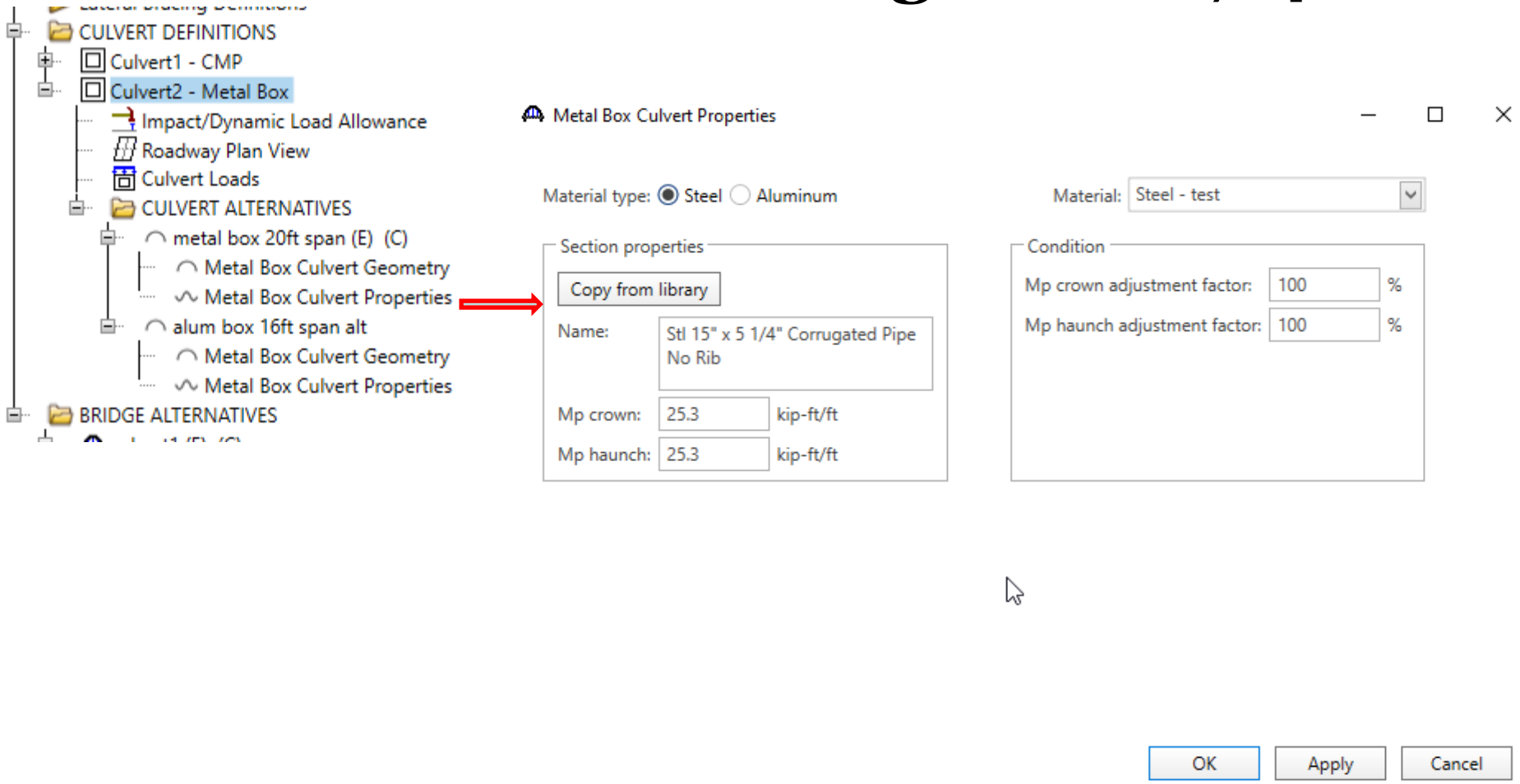

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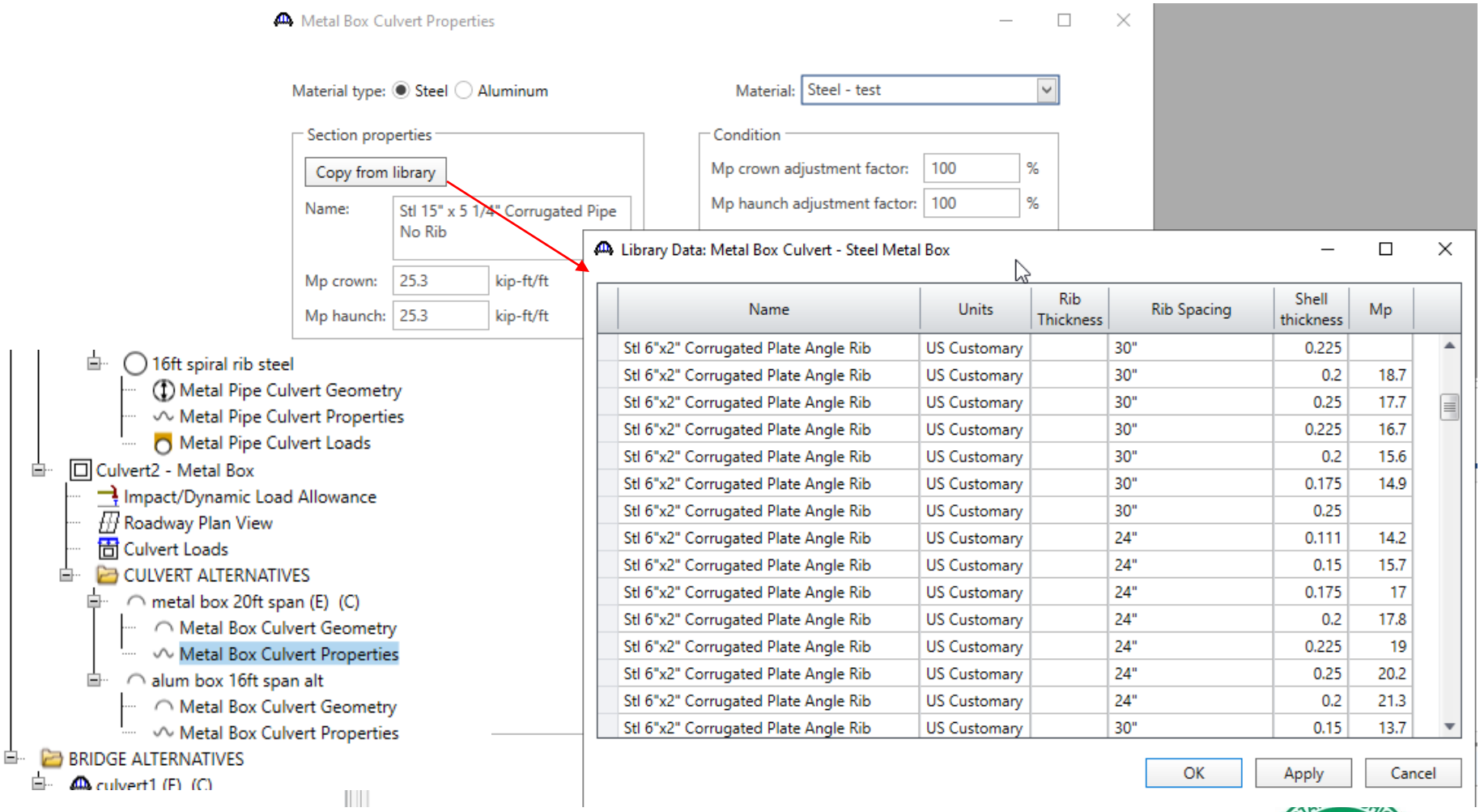

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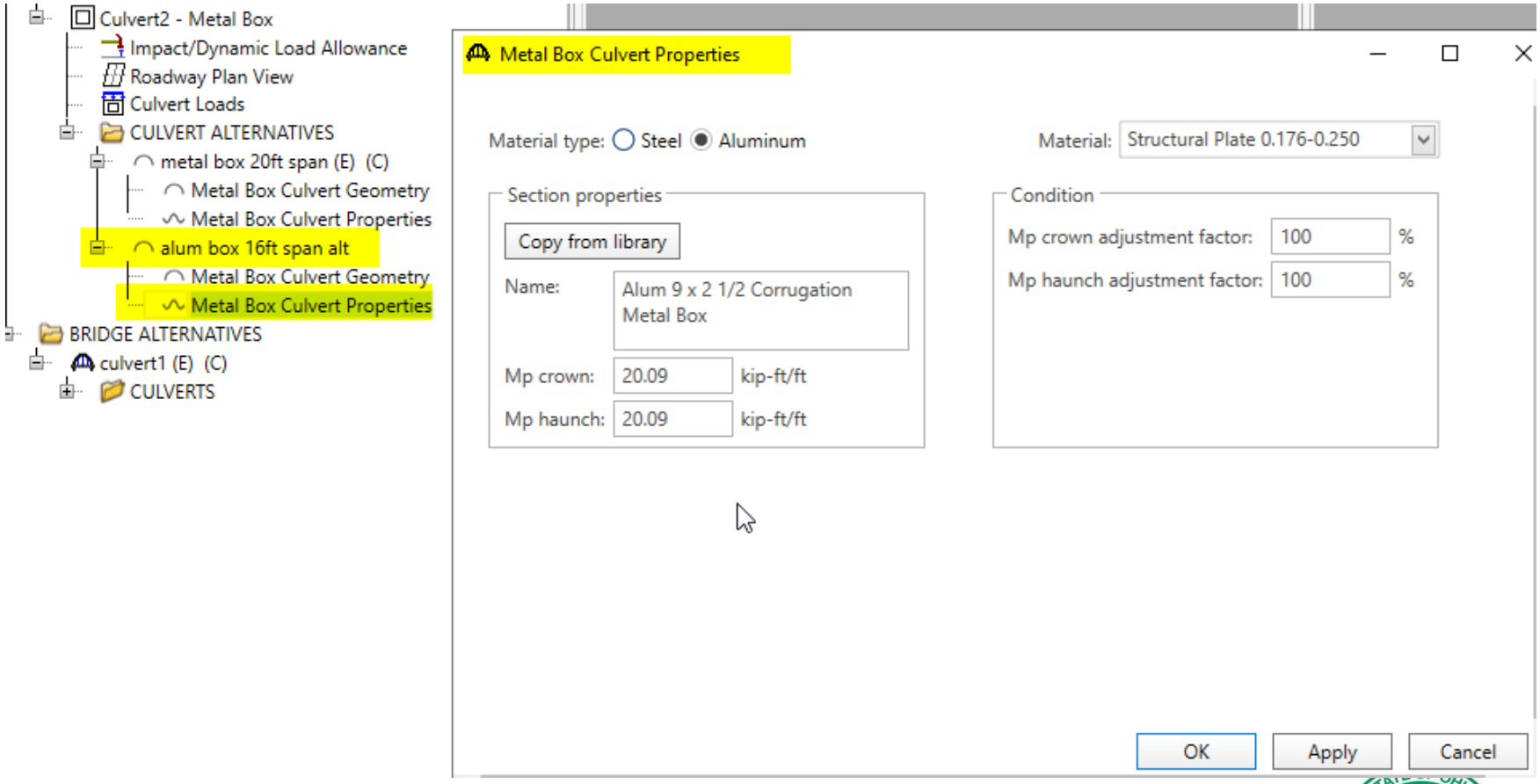
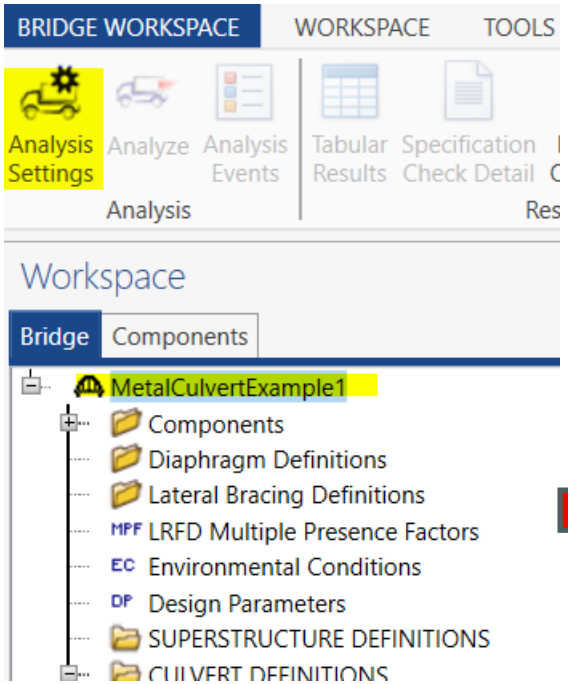
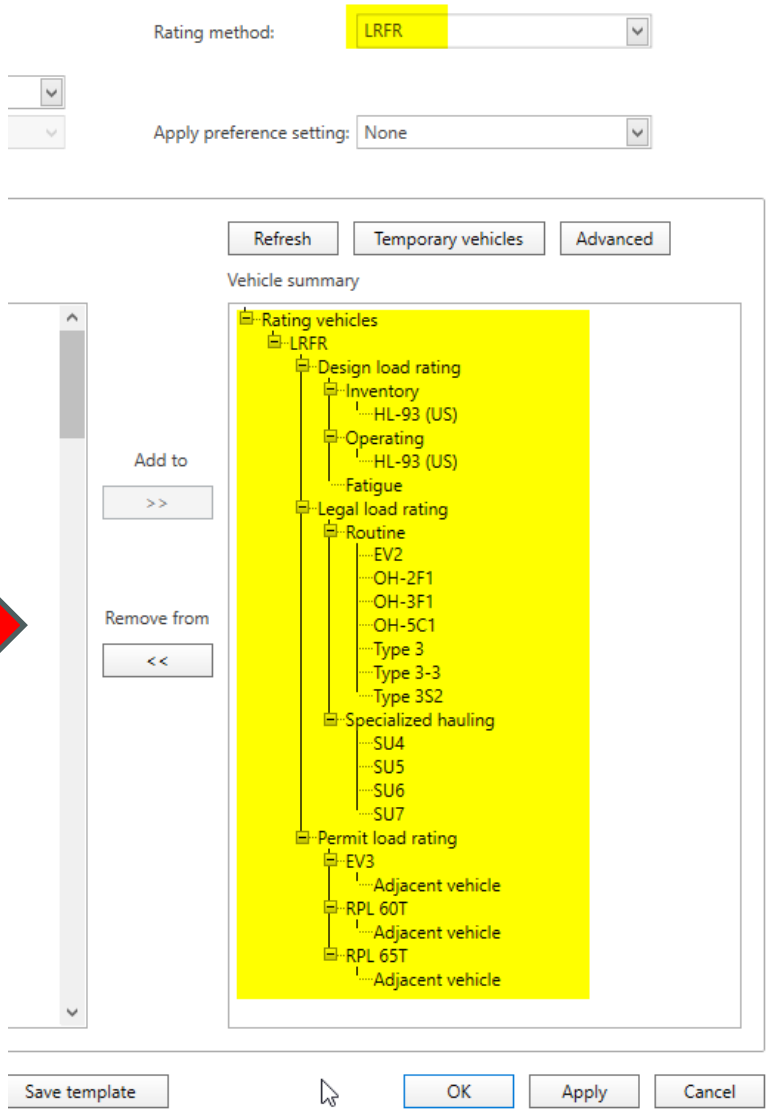


Metal Culvert Rating in BrR 7.4.1

Analysis setting





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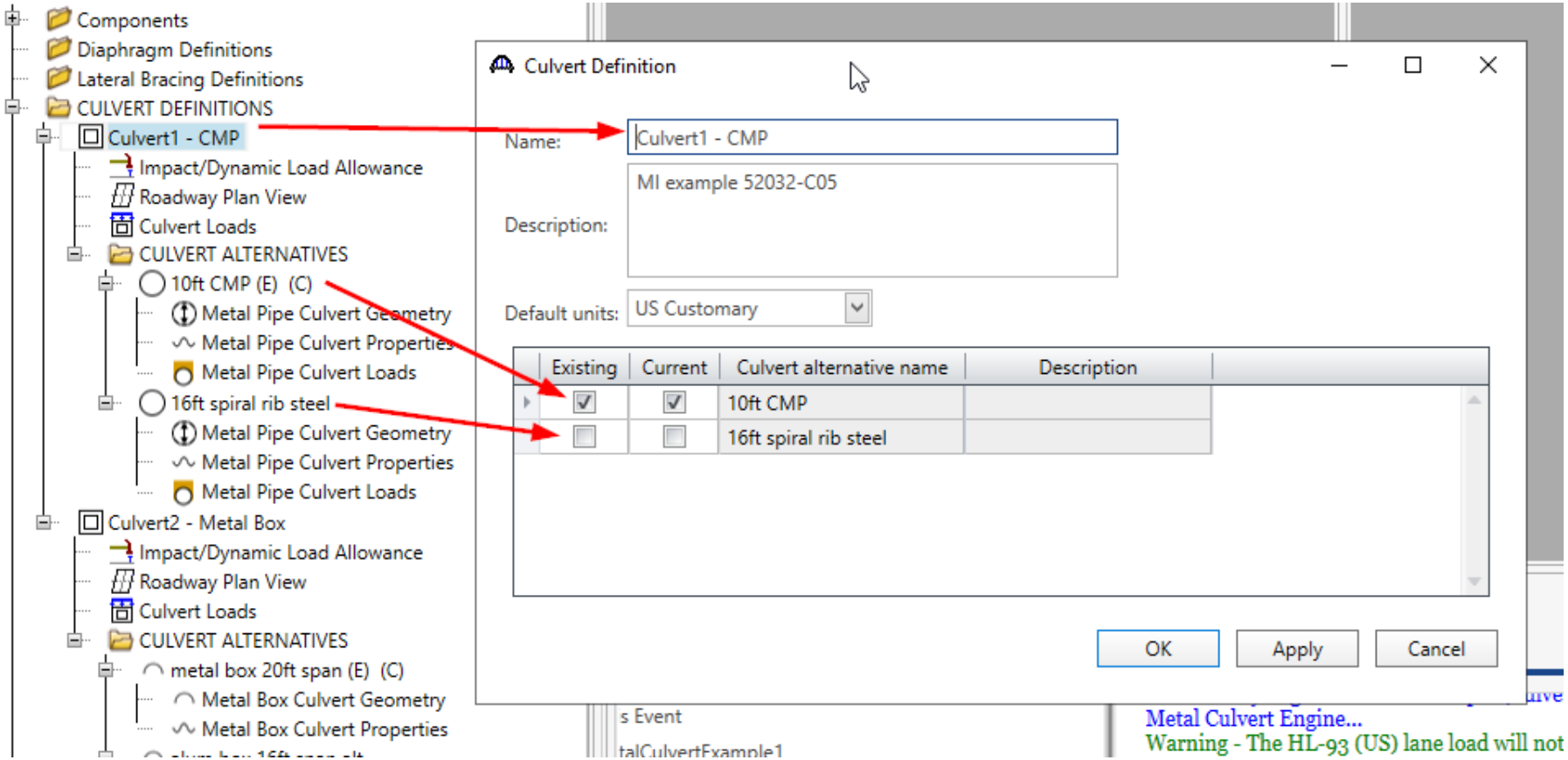

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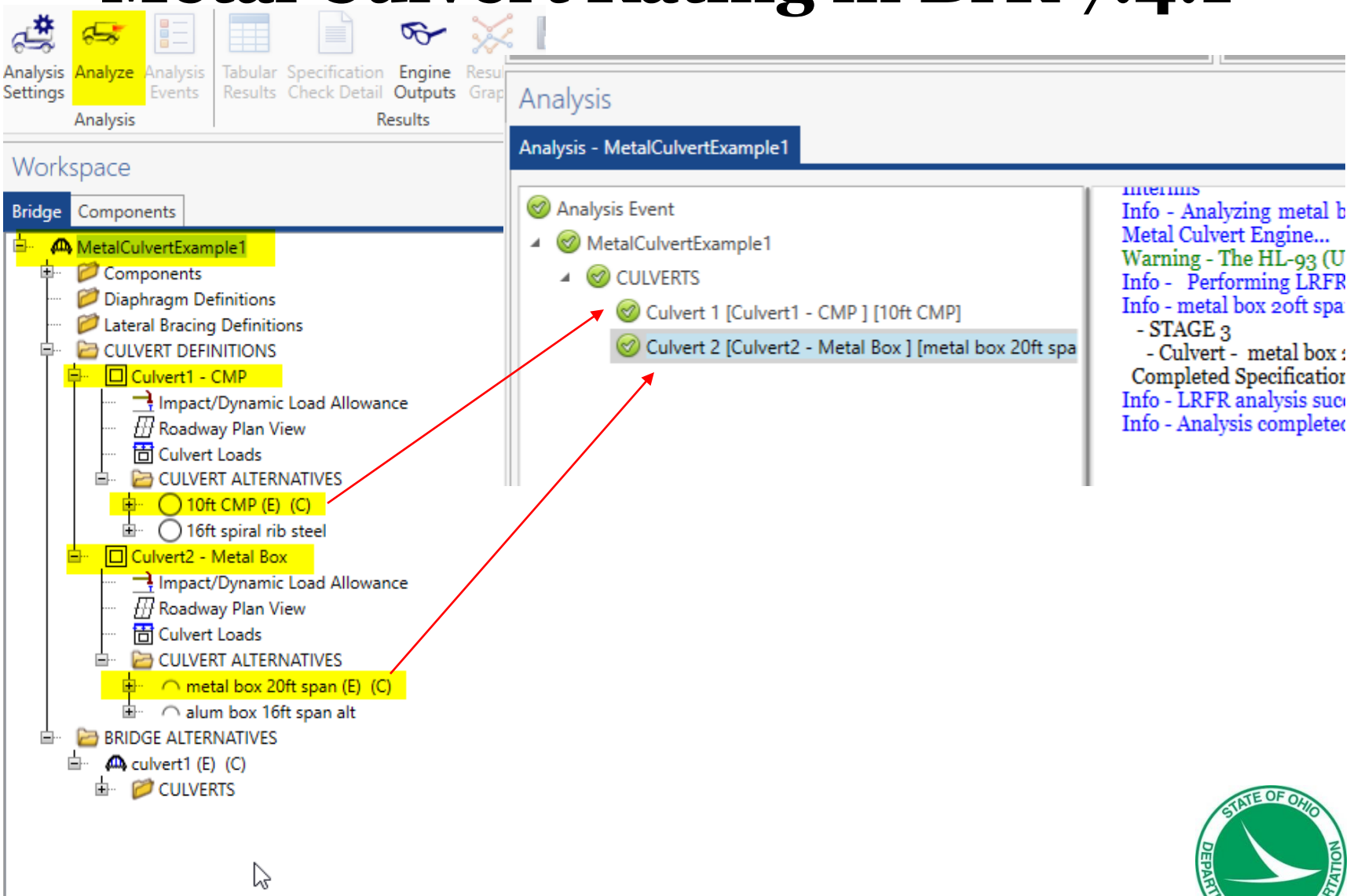

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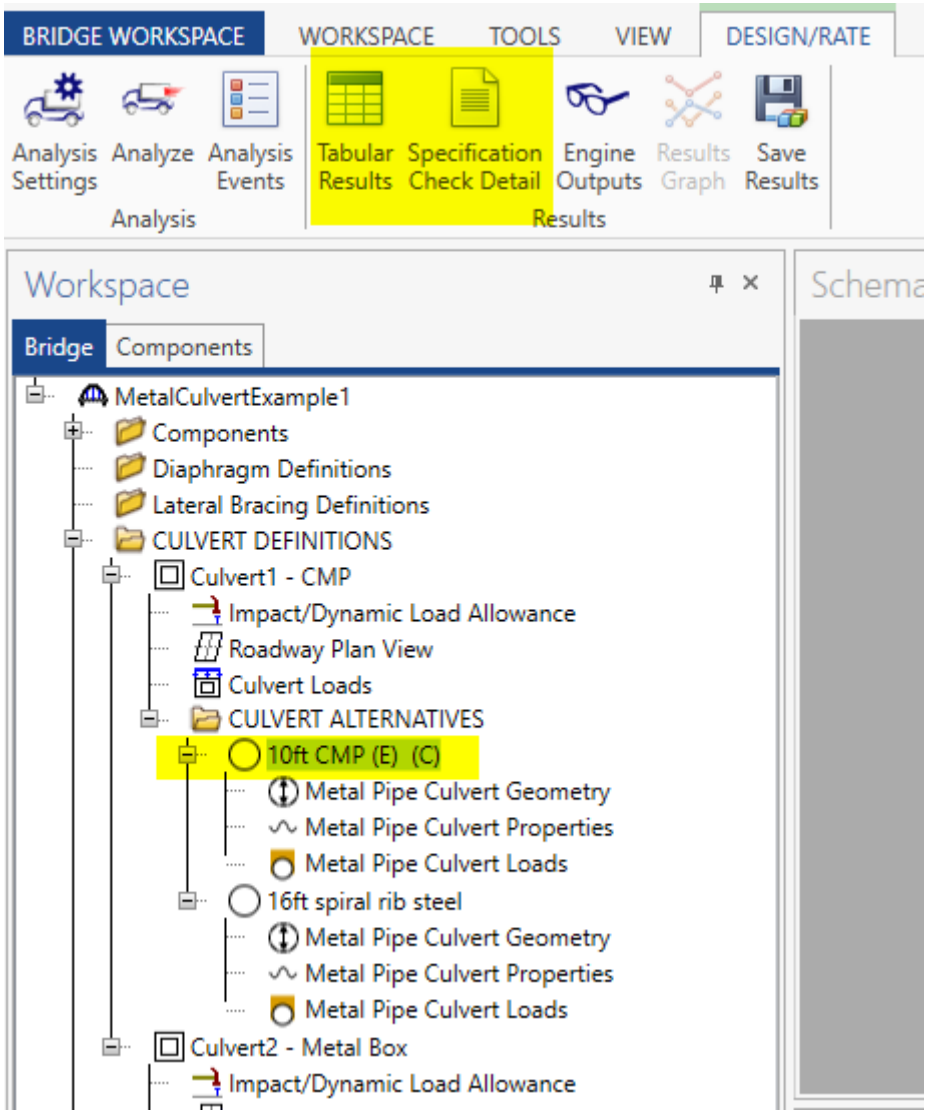
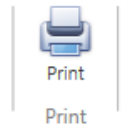


Metal Culvert Rating in BrR 7.4.1

RESULTS - Workspace



Report type: Rating Results Summary

Lane/Impact loading type: (•) As requested ( ) Detailed

Display Format: Single rating level per row

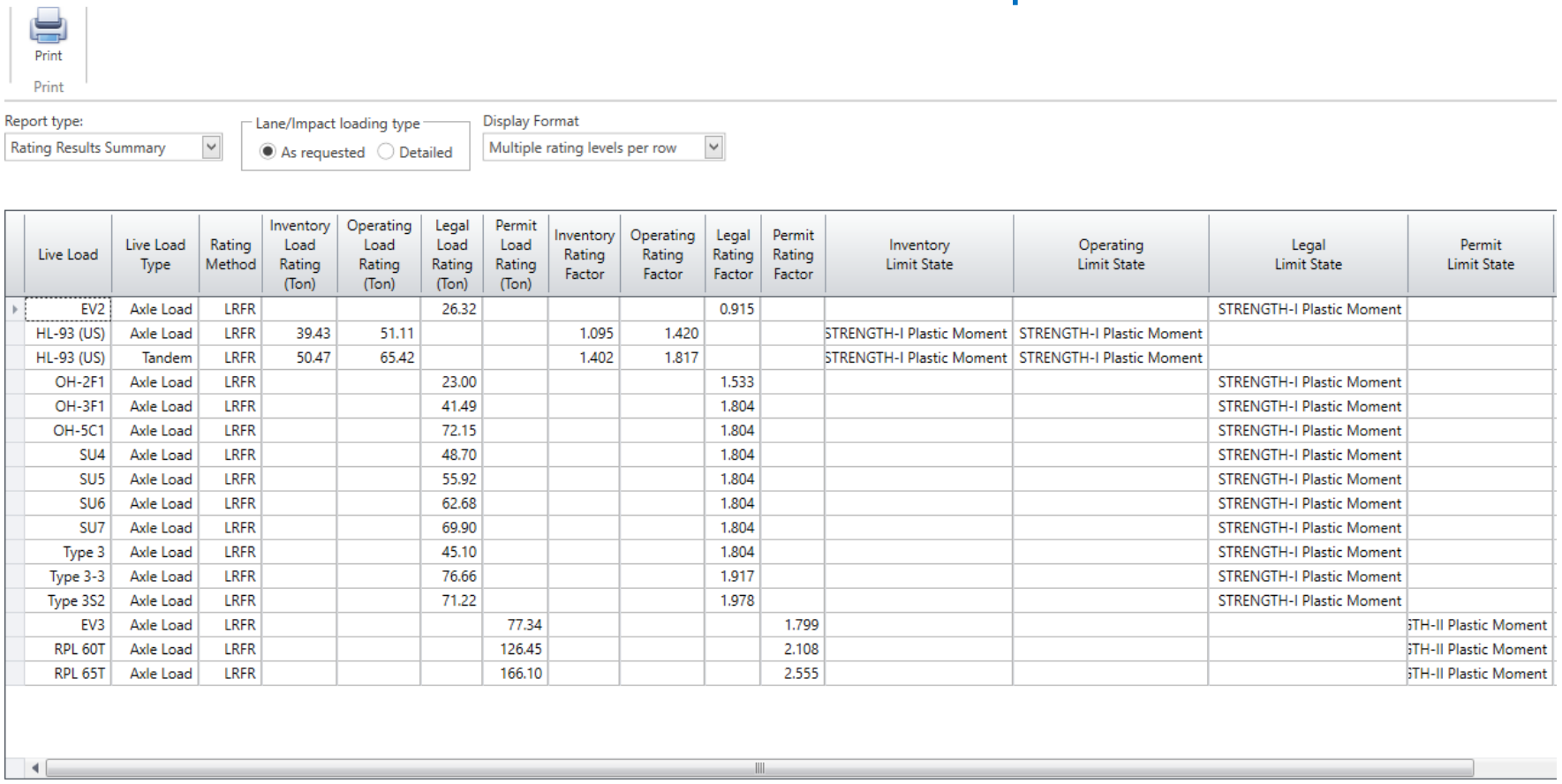
Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Limit State	Impact	Lane
EV2	Axle Load	LRFR	Legal	26.32	0.915	STRENGTH-I Plastic Moment	As Requested	As Requested
HL-93 (US)	Axle Load	LRFR	Inventory	39.43	1.095	STRENGTH-I Plastic Moment	As Requested	As Requested
HL-93 (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
OH-2F1	Axle Load	LRFR	Legal	23.00	1.533	STRENGTH-I Plastic Moment	As Requested	As Requested
OH-3F1	Axle Load	LRFR	Legal	41.49	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
OH-5C1	Axle Load	LRFR	Legal	72.15	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
SU4	Axle Load	LRFR	Legal	48.70	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
SU5	Axle Load	LRFR	Legal	55.92	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
SU6	Axle Load	LRFR	Legal	62.68	1.804	STRENGTH-I Plastic Moment	As Requested	As Requested
SU7	Axle Load	LRFR	Legal	69.90	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
EV3	Axle Load	LRFR	Permit	77.34	1.799	STRENGTH-II Plastic Moment	As Requested	As Requested
RPL 60T	Axle Load	LRFR	Permit	126.45	2.108	STRENGTH-II Plastic Moment	As Requested	As Requested
RPL 65T	Axle Load	LRFR	Permit	166.10	2.555	STRENGTH-II Plastic Moment	As Requested	As Requested

AASHTO Metal Culvert LRFR Engine Version 7.4.1.3001

Analysis preference setting: None

Metal Culvert Rating in BrR 7.4.1

RESULTS - Workspace



Live Load	Live Load Type	Rating Method	Inventory Load Rating (Ton)	Operating Load Rating (Ton)	Legal Load Rating (Ton)	Permit Load Rating (Ton)	Inventory Rating Factor	Operating Rating Factor	Legal Rating Factor	Permit Rating Factor	Inventory Limit State	Operating Limit State	Legal Limit State	Permit Limit State
EV2	Axle Load	LRFR			26.32				0.915				STRENGTH-I Plastic Moment	
HL-93 (US)	Axle Load	LRFR	39.43	51.11			1.095	1.420			STRENGTH-I Plastic Moment	STRENGTH-I Plastic Moment		
HL-93 (US)	Tandem	LRFR	50.47	65.42			1.402	1.817			STRENGTH-I Plastic Moment	STRENGTH-I Plastic Moment		
OH-2F1	Axle Load	LRFR			23.00				1.533				STRENGTH-I Plastic Moment	
OH-3F1	Axle Load	LRFR			41.49				1.804				STRENGTH-I Plastic Moment	
OH-5C1	Axle Load	LRFR			72.15				1.804				STRENGTH-I Plastic Moment	
SU4	Axle Load	LRFR			48.70				1.804				STRENGTH-I Plastic Moment	
SU5	Axle Load	LRFR			55.92				1.804				STRENGTH-I Plastic Moment	
SU6	Axle Load	LRFR			62.68				1.804				STRENGTH-I Plastic Moment	
SU7	Axle Load	LRFR			69.90				1.804				STRENGTH-I Plastic Moment	
Type 3	Axle Load	LRFR			45.10				1.804				STRENGTH-I Plastic Moment	
Type 3-3	Axle Load	LRFR			76.66				1.917				STRENGTH-I Plastic Moment	
Type 3S2	Axle Load	LRFR			71.22				1.978				STRENGTH-I Plastic Moment	
EV3	Axle Load	LRFR				77.34				1.799				STH-II Plastic Moment
RPL 60T	Axle Load	LRFR				126.45				2.108				STH-II Plastic Moment
RPL 65T	Axle Load	LRFR				166.10				2.555				STH-II Plastic Moment

AASHTO Metal Culvert LRFR Engine Version 7.4.1.3001

Metal Culvert Rating in BrR 7.4.1

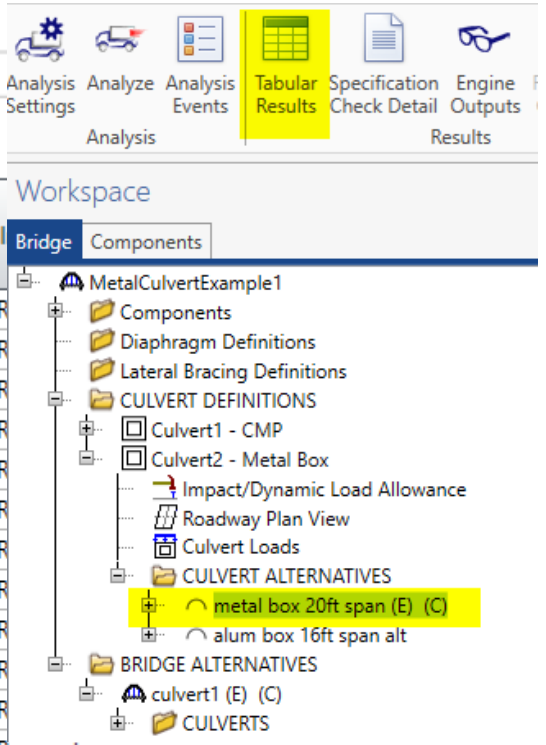
Report type: Rating Results Summary

Lane/Impact loading type: (●) As requested ( ) Detailed

Display Format: Single rating level per row

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Limit State	
EV2	Axle Load	LRFR	Legal	41.38	1.439	STRENGTH-I Plastic Moment	As R
HL-93 (US)	Axle Load	LRFR	Inventory	39.02	1.084	STRENGTH-I Plastic Moment	As R
HL-93 (US)	Axle Load	LRFR	Operating	57.81	1.606	STRENGTH-I Plastic Moment	As R
HL-93 (US)	Tandem	LRFR	Inventory	49.70	1.380	STRENGTH-I Plastic Moment	As R
HL-93 (US)	Tandem	LRFR	Operating	73.63	2.045	STRENGTH-I Plastic Moment	As R
OH-2F1	Axle Load	LRFR	Legal	40.77	2.718	STRENGTH-I Plastic Moment	As R
OH-3F1	Axle Load	LRFR	Legal	41.17	1.790	STRENGTH-I Plastic Moment	As R
OH-5C1	Axle Load	LRFR	Legal	71.60	1.790	STRENGTH-I Plastic Moment	As R
SU4	Axle Load	LRFR	Legal	41.32	1.530	STRENGTH-I Plastic Moment	As R
SU5	Axle Load	LRFR	Legal	51.15	1.650	STRENGTH-I Plastic Moment	As R
SU6	Axle Load	LRFR	Legal	49.59	1.427	STRENGTH-I Plastic Moment	As R
SU7	Axle Load	LRFR	Legal	48.73	1.258	STRENGTH-I Plastic Moment	As Requeste
Type 3	Axle Load	LRFR	Legal	41.25	1.650	STRENGTH-I Plastic Moment	As Requeste
Type 3-3	Axle Load	LRFR	Legal	74.78	1.870	STRENGTH-I Plastic Moment	As Requeste
Type 3S2	Axle Load	LRFR	Legal	72.11	2.003	STRENGTH-I Plastic Moment	As Requeste
EV3	Axle Load	LRFR	Permit	75.85	1.764	STRENGTH-II Plastic Moment	As Requeste
RPL 60T	Axle Load	LRFR	Permit	134.75	2.246	STRENGTH-II Plastic Moment	As Requeste
RPL 65T	Axle Load	LRFR	Permit	128.60	1.978	STRENGTH-II Plastic Moment	As Requeste

AASHTO Metal Culvert LRFR Engine Version 7.4.1.3001



Metal Culvert Rating in BrR 7.4.1

RESULTS – Bridge Explorer

Bridge Rating Results

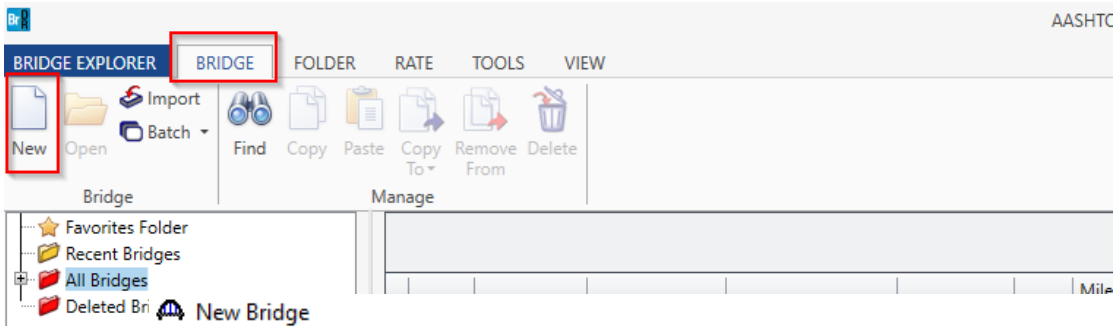
System of units: (●) US customary ( ) SI / metric

Lane/impact loading type: (●) As requested ( ) Detailed

Display format: Single rating level per row

Bridge ID	Vehicle	Rating level	Rating factor	Rating method	Capacity (Ton)	Time stamp	Rated by
MetalCulvertExample1	EV2	Legal	0.915	LRFR	26.317	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	HL-93 (US)	Inventory	1.084	LRFR	39.024	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	HL-93 (US)	Operating	1.420	LRFR	51.109	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	OH-2F1	Legal	1.533	LRFR	22.999	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	OH-3F1	Legal	1.790	LRFR	41.171	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	OH-5C1	Legal	1.790	LRFR	71.602	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	SU4	Legal	1.530	LRFR	41.319	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	SU5	Legal	1.650	LRFR	51.148	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	SU6	Legal	1.427	LRFR	49.589	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	SU7	Legal	1.258	LRFR	48.728	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	Type 3	Legal	1.650	LRFR	41.249	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	Type 3-3	Legal	1.870	LRFR	74.781	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	Type 3S2	Legal	1.978	LRFR	71.222	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	EV3	Permit	1.764	LRFR	75.848	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	RPL 60T	Permit	2.108	LRFR	126.455	Thursday, August 3, 2023 11:53:...	awaheed
MetalCulvertExample1	RPL 65T	Permit	1.978	LRFR	128.602	Thursday, August 3, 2023 11:53:...	awaheed

Metal Culvert Rating in BrR 7.4.1



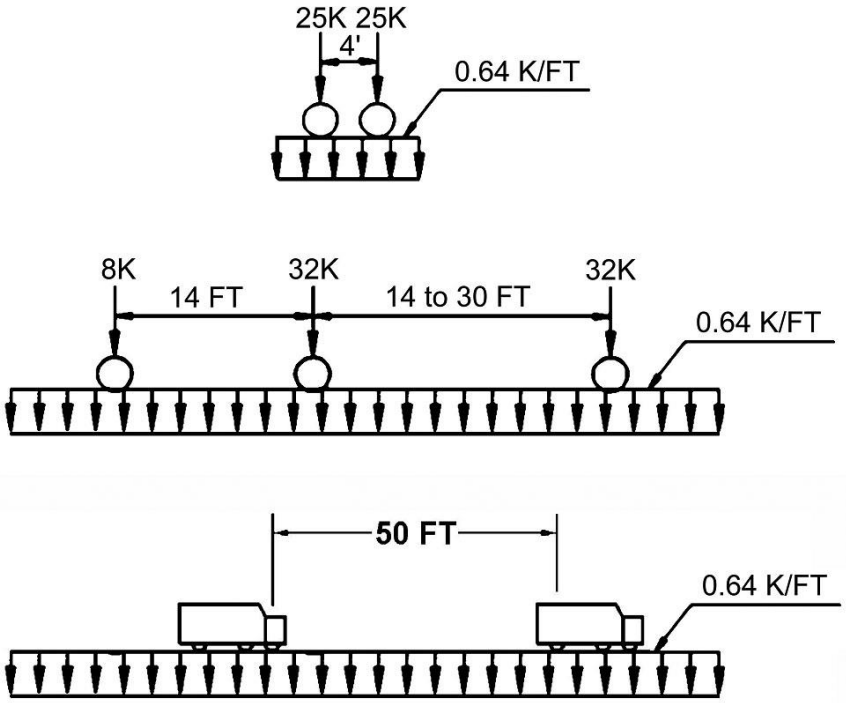
Bridge ID: 4706693 NBI structure ID (8): 4706693

Template
Bridge completely defined
Superstructures
Culverts
Substructures

Description | Description (cont'd) | Alternatives | Global reference point | Traffic | Custom agency fields

Name:	LOR-301-2256	Year built:	2017
Description:	CMP Culvert		
Location:	0.29 Mi N of SR 254	Length:	15 ft
Facility carried (7):	SR 301	Route number:	301
Feat. intersected (6):	Ditch	Mi. post:	22.56
Default units:	US Customary		

Metal Culvert Rating in BrR 7.4.1

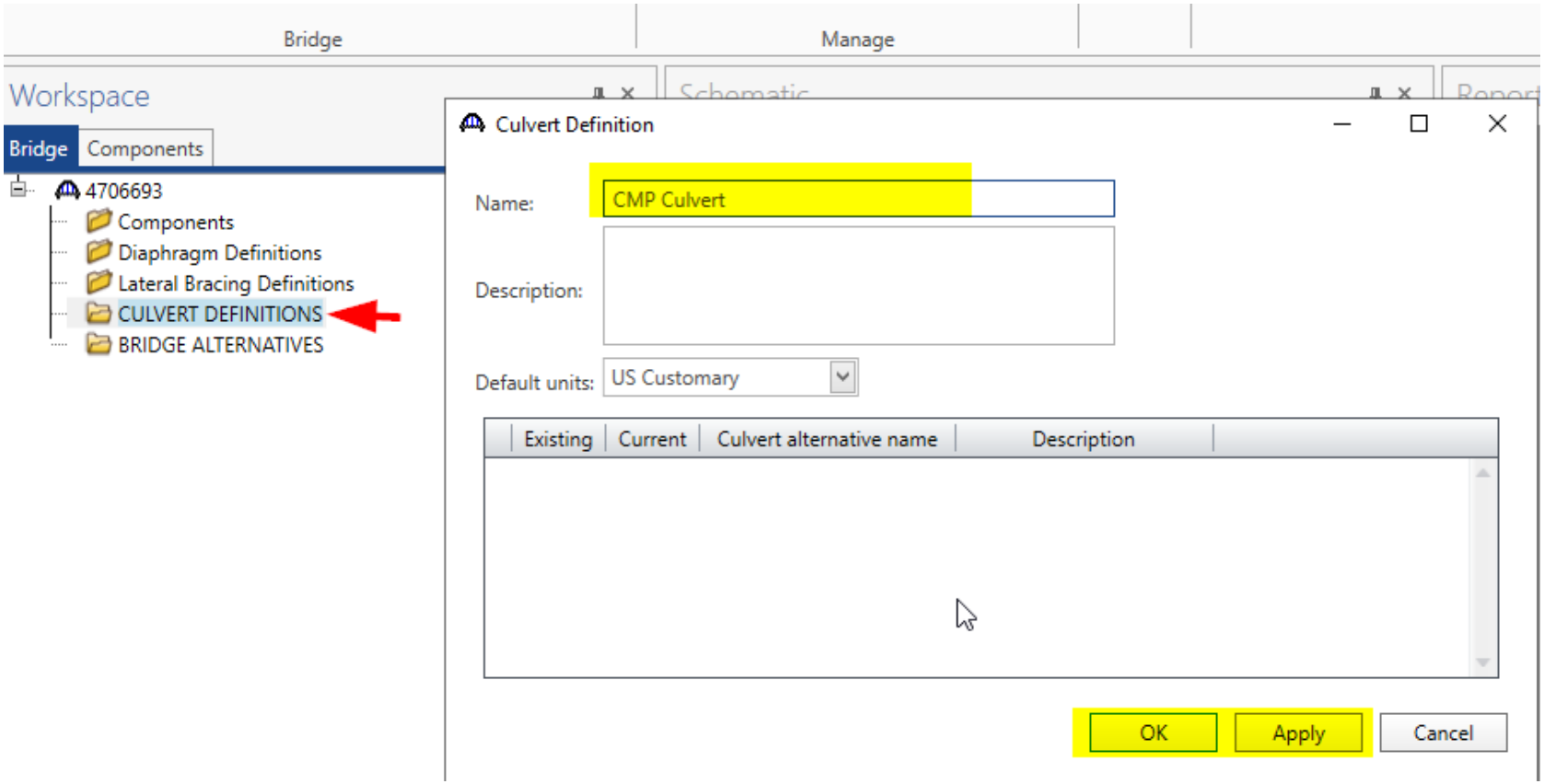


All Axle Loads in kips

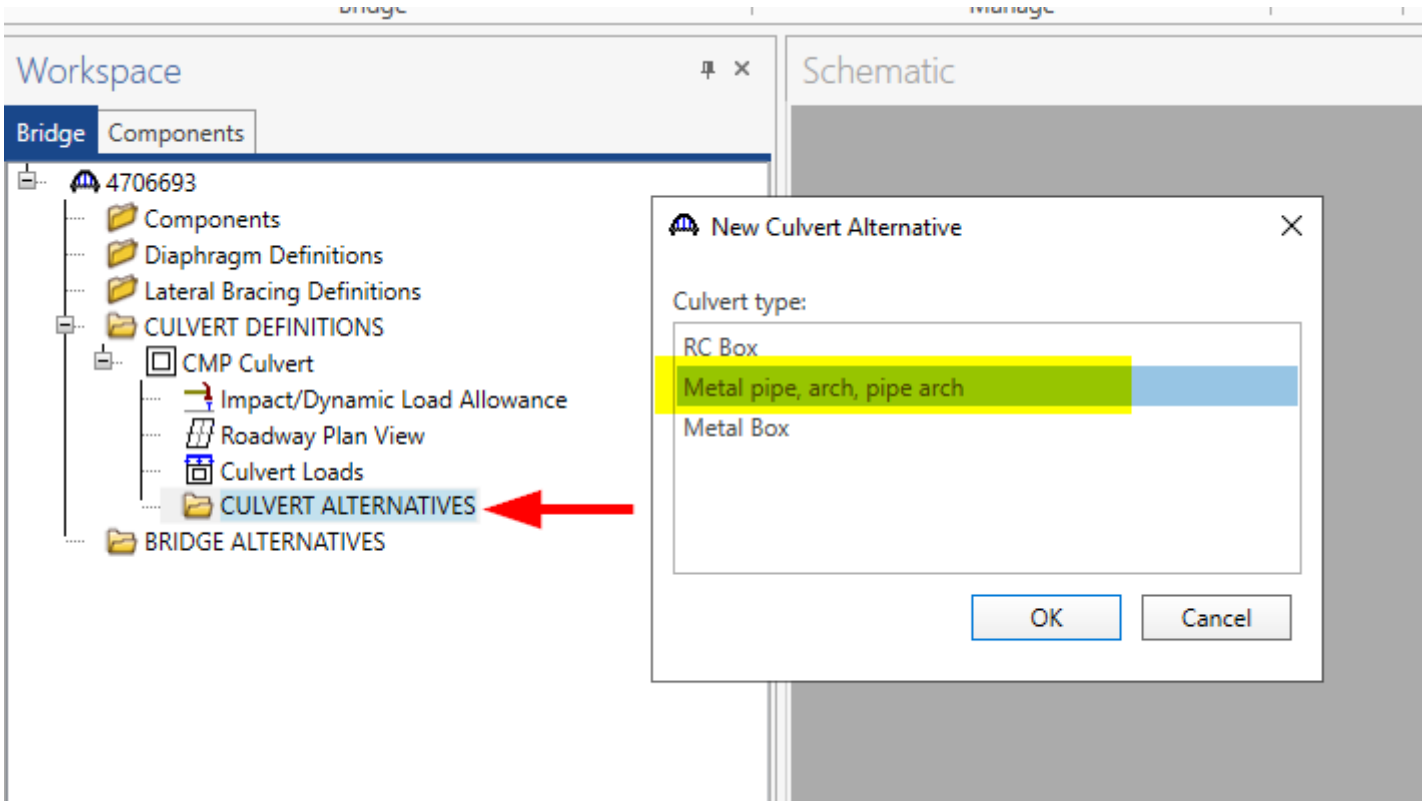
EV2, weight = 57.5 kips (28.75 tons)

HL-93 Design Loading

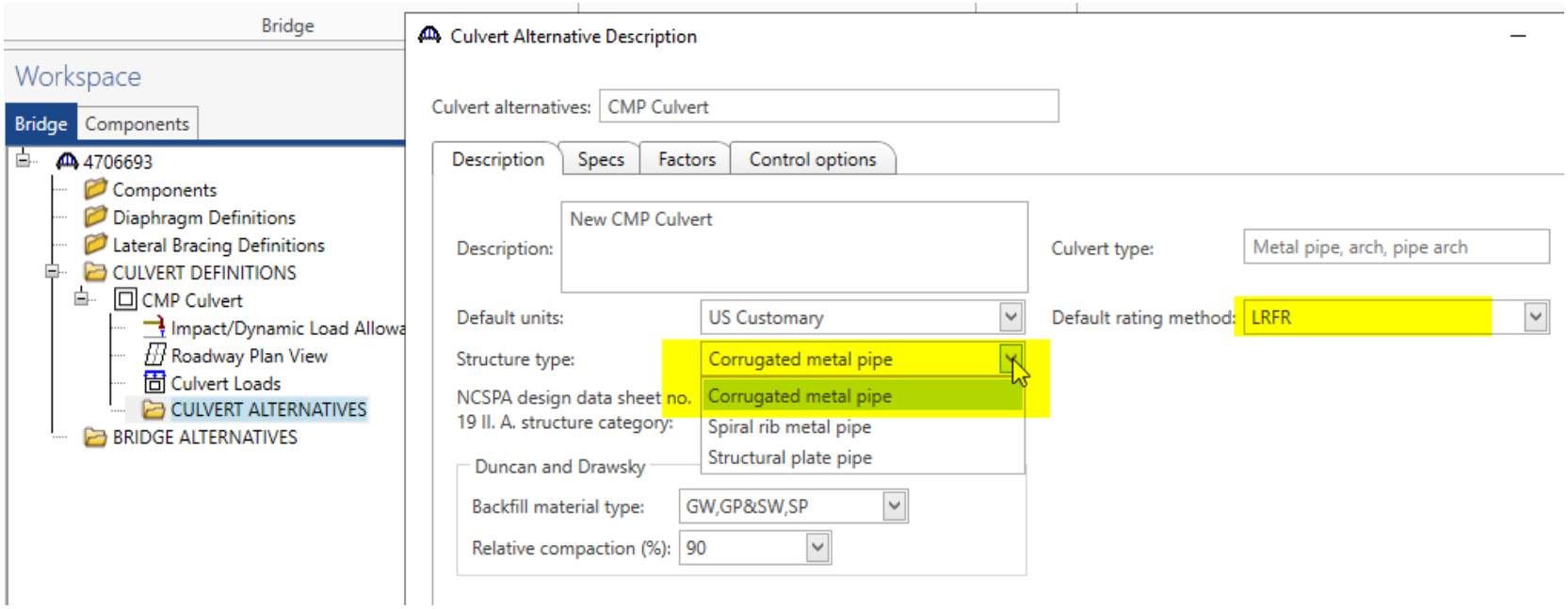
Metal Culvert Rating in BrR 7.4.1



Metal Culvert Rating in BrR 7.4.1



Metal Culvert Rating in BrR 7.4.1



Questions

Amjad Waheed, PE
OHDOT Bridge Rating Engineer

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614-752-9972