AASHTOWare™

BRIDGE

DESIGN AND RATING

Culvert SSI Implementation Update

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ProMiles

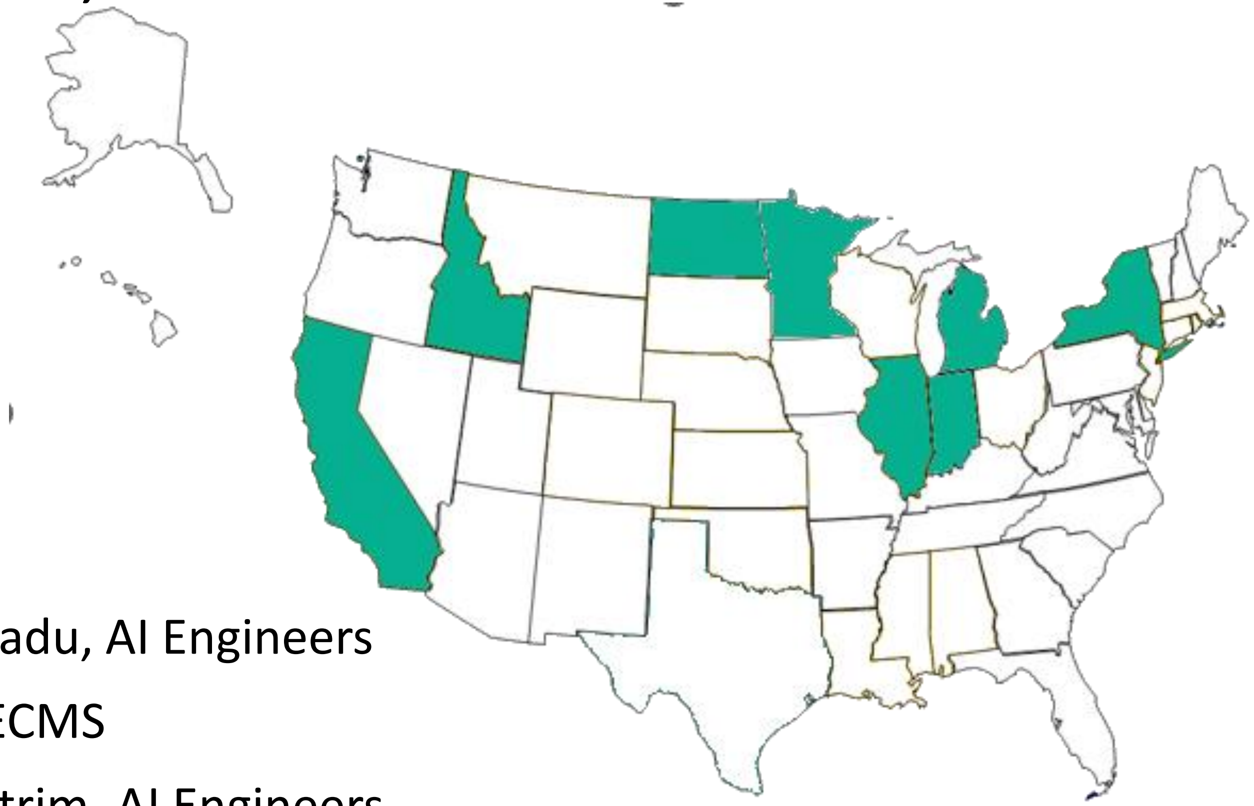
Culvert SSI Update

- Introduction
- Engine validation updates (Phase 1)
- Concrete interface (Phase 2.1)
- Future phases (Phase 2.2 and beyond)

Culvert SSI Implementation Update

Culvert TAG participants – 9 DOTs, 3 consultants

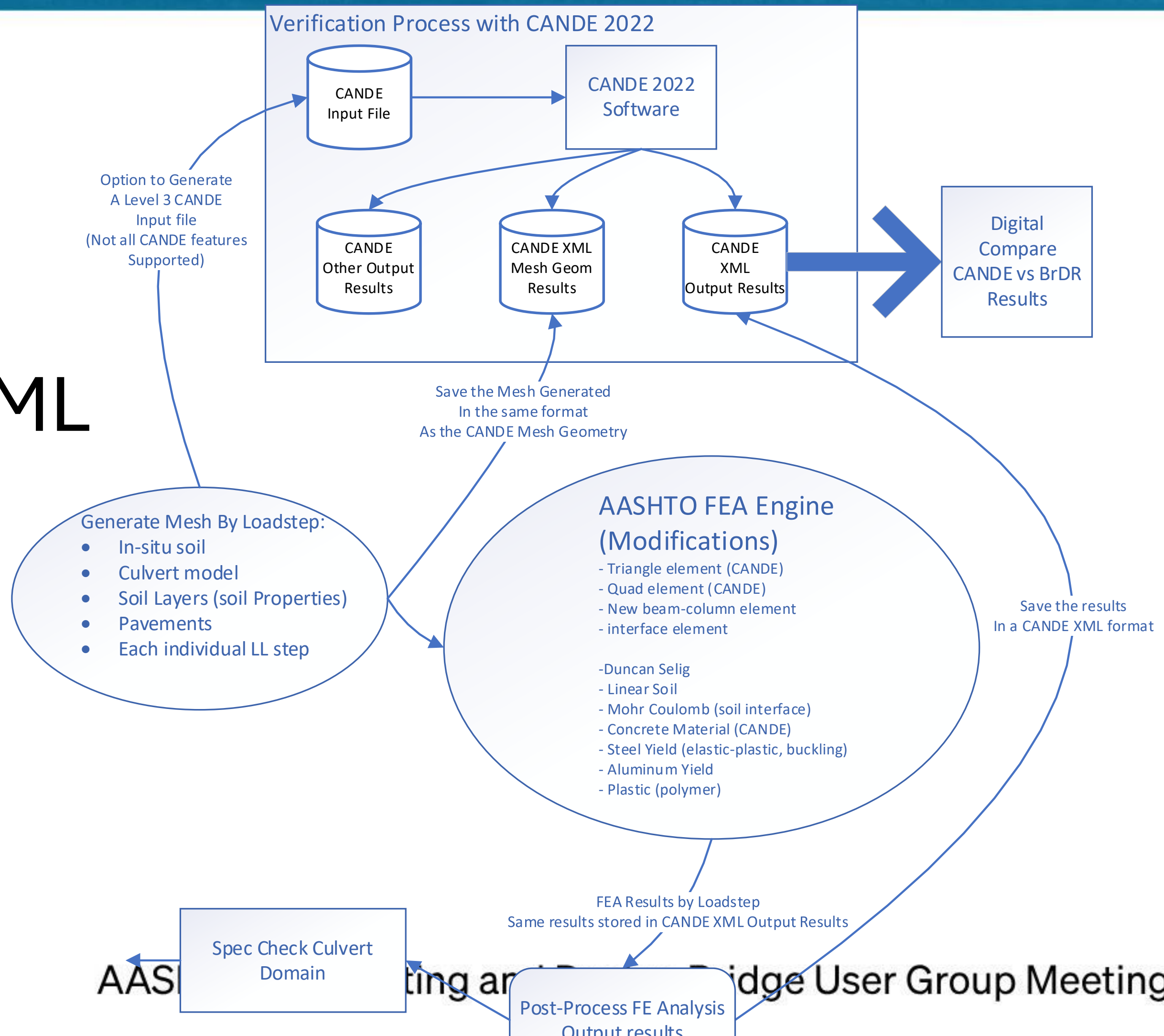
- Mike Johnson, Idaho TD, Chair
- Matt Luger, North Dakota DOT, Vice-Chair
- Mark Mlynarski, ProMiles
- Ruben Boehler, Illinois DOT
- Yihong Gao, Minnesota DOT
- Jennifer Hart, Indiana DOT
- Ratan Huda, New York DOT
- Spencer Koehler, Illinois DOT
- Don Tempinson, Michigan DOT
- Richard Tsang, CalTrans
- Elizabeth Befikadu, AI Engineers
- Nevil Gomes, ECMS
- Damian Silverstrim, AI Engineers



Phase 1

Culvert SSI Implementation Update- Validation

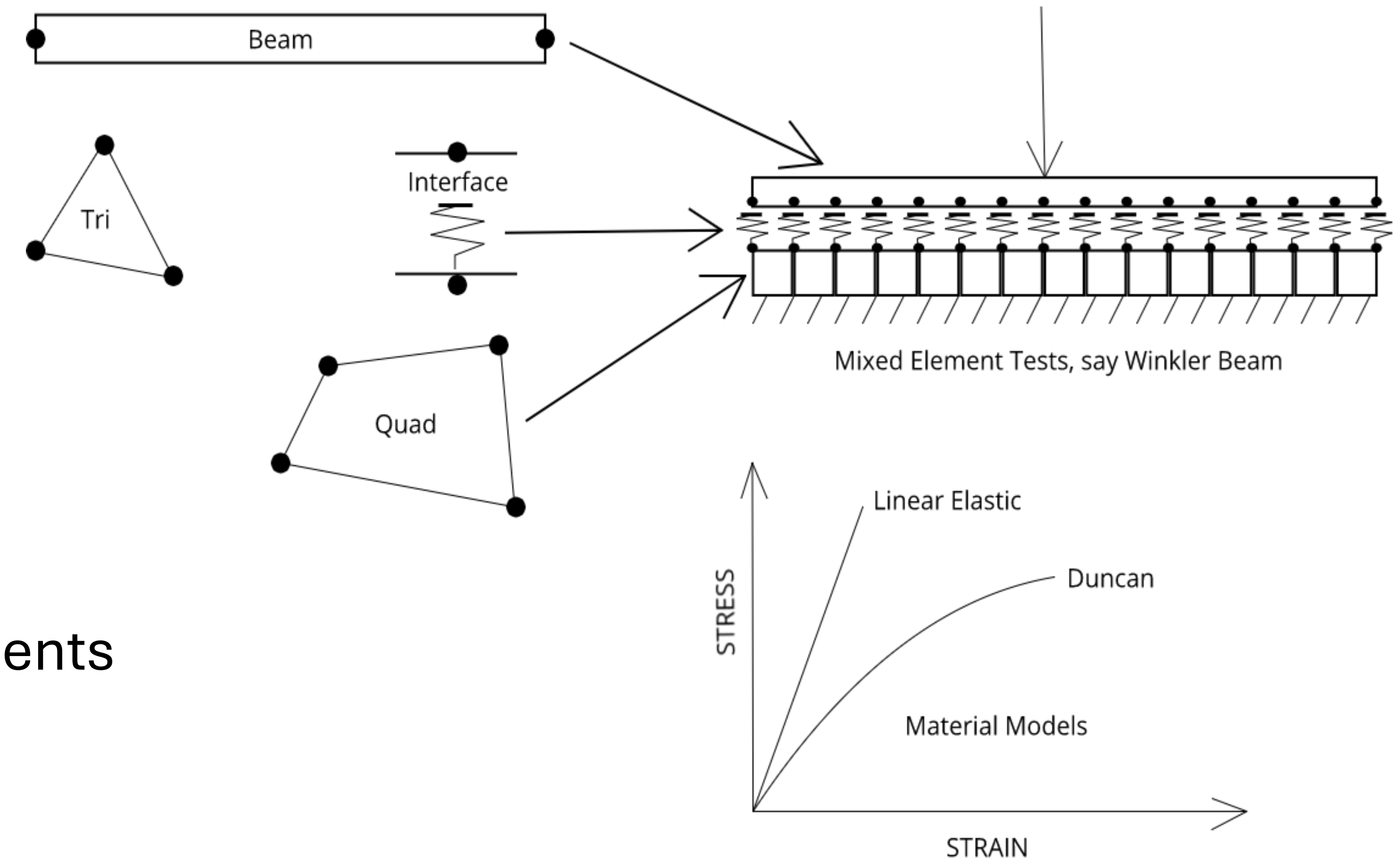
- Validation Process
- Use new engine with SSI elements
- Produce output in CANDE XML format
- Digital (or graphical) comparison of results for various models



Phase 1

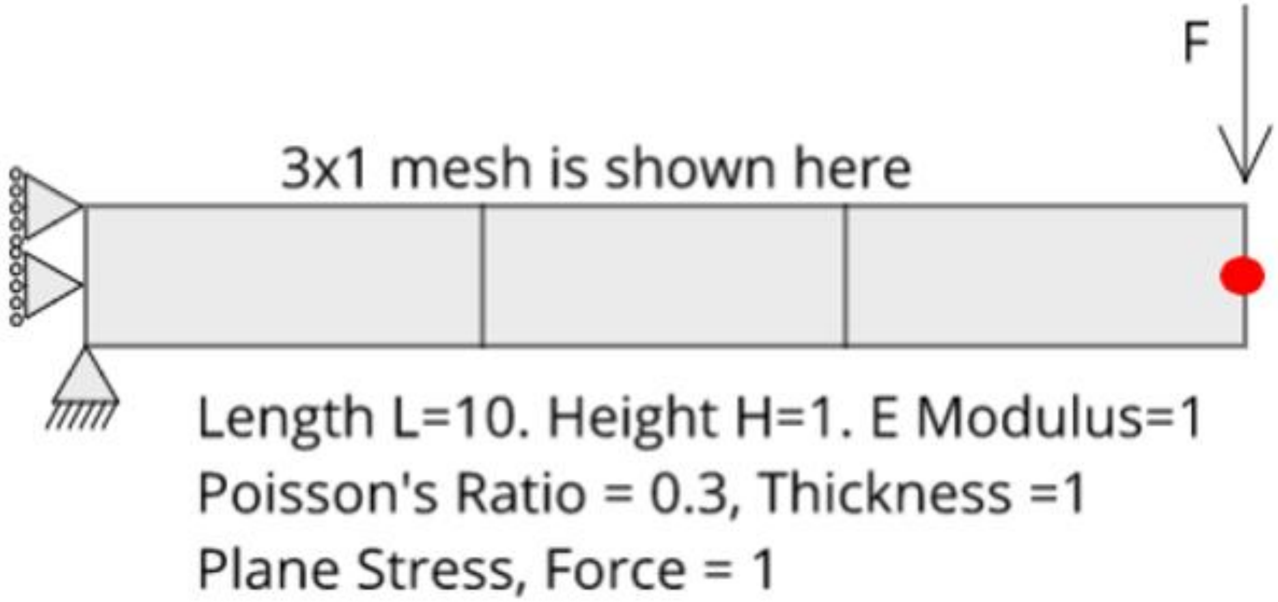
Culvert SSI Implementation Update-Validation

- Small model validation
- Highly focused unit tests
- Verify the performance of
  - Beam
  - Quadrilateral
  - Triangle
  - Interface
  - Linearly elastic and Duncan materials
- Integrated, focused – combine elements
- Make sure the parts are functioning individually and in small models



Culvert SSI Implementation Update-Validation

- Focused Element tests
- Quadrilateral tests
  - Simple test BrDR matched CANDE and was within 3% of beam theory for a small number of elements



Culvert SSI Implementation Update-Validation

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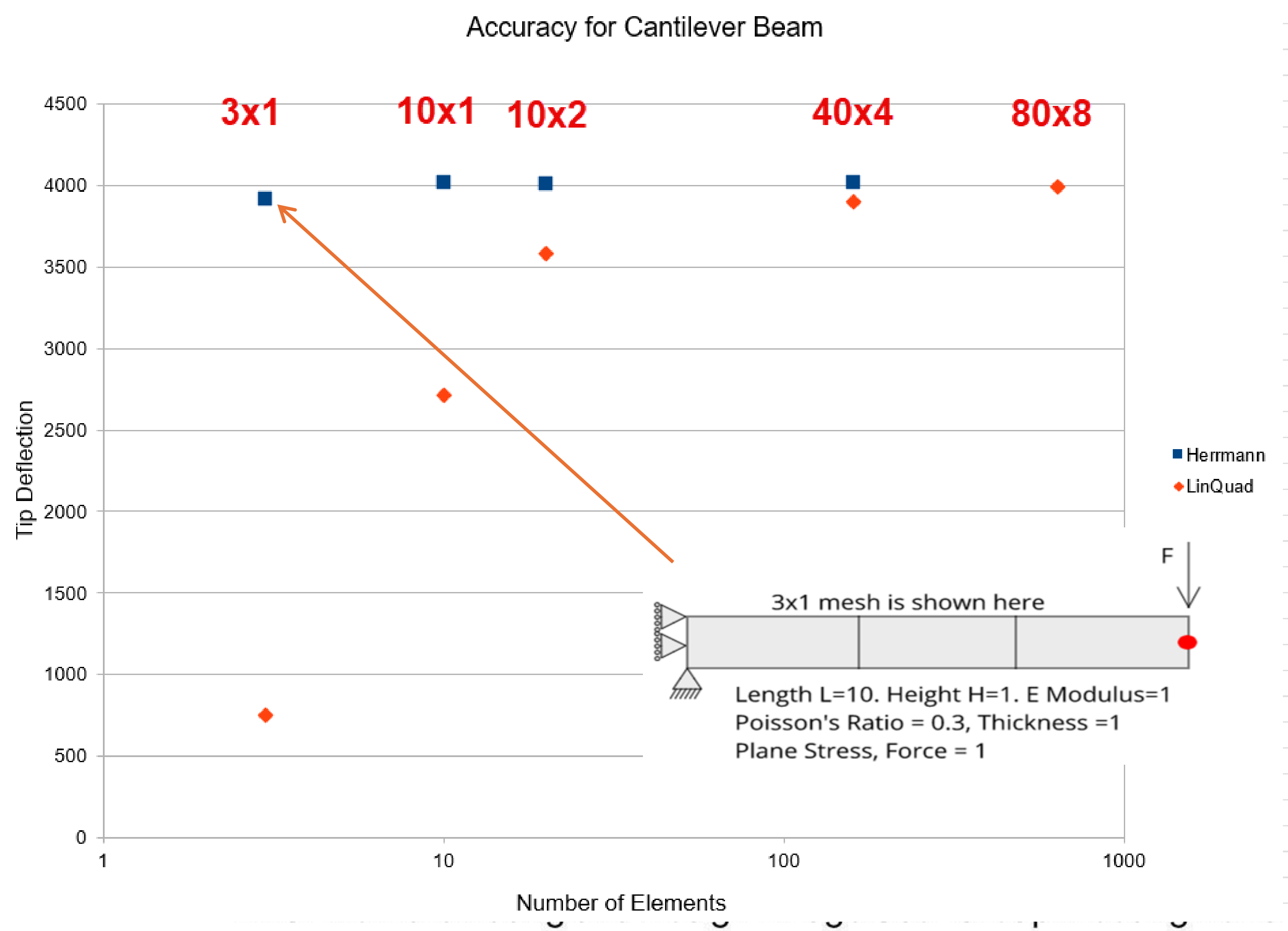

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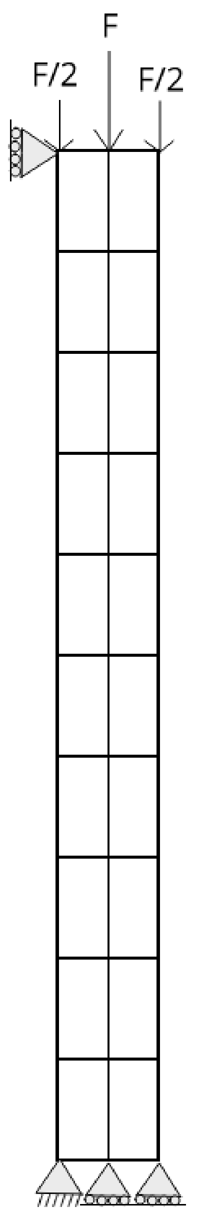
Phase 1

Culvert SSI Implementation Update-Validation

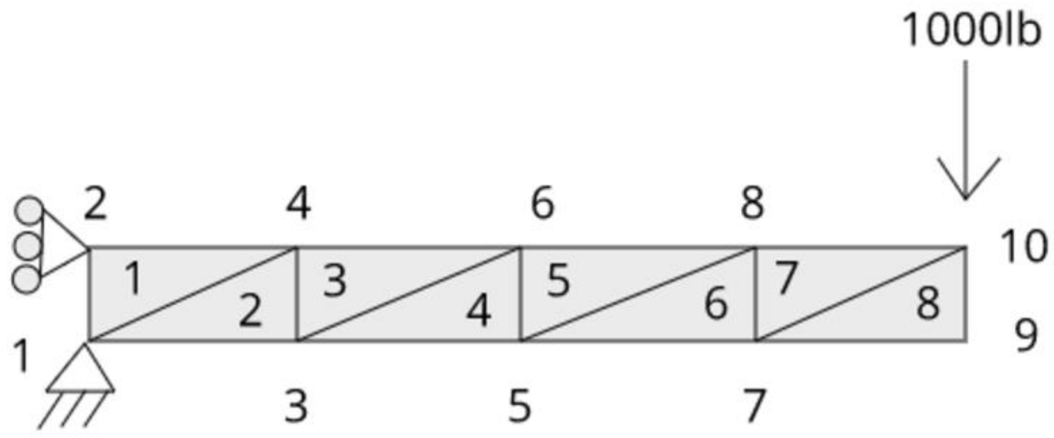


- Focused Element tests
- Quadrilateral tests
  - Column tests, shown to the right, were compared against theory with and without density to confirm that body forces are handled correctly

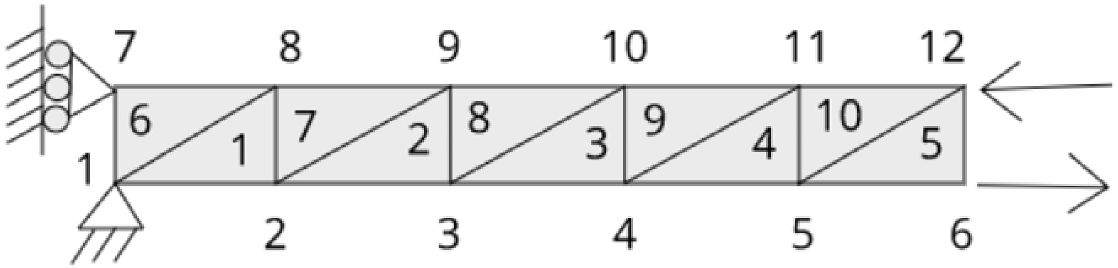
Phase 1

Culvert SSI Implementation Update-Validation

- Focused Element tests
- Triangle tests
  - BrDR/CANDE matches for cantiever
  - BrDR/CANDE matches for pure bending



Triangle Mesh



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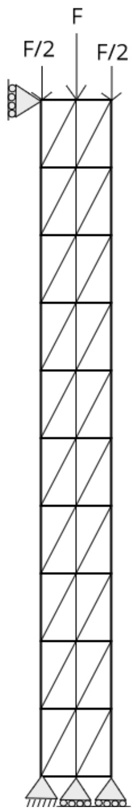
Culvert SSI Implementation Update-Validation

- Focused Element tests
- Triangle tests
  - Column tests, shown to the right, were compared against theory with and without density to confirm that body forces are handled correctly
  - BrDR/CANDE matching



Culvert SSI Implementation Update-Validation

- Focused Element tests
- Duncan Material Testing
  - Simple model with axial and lateral loads

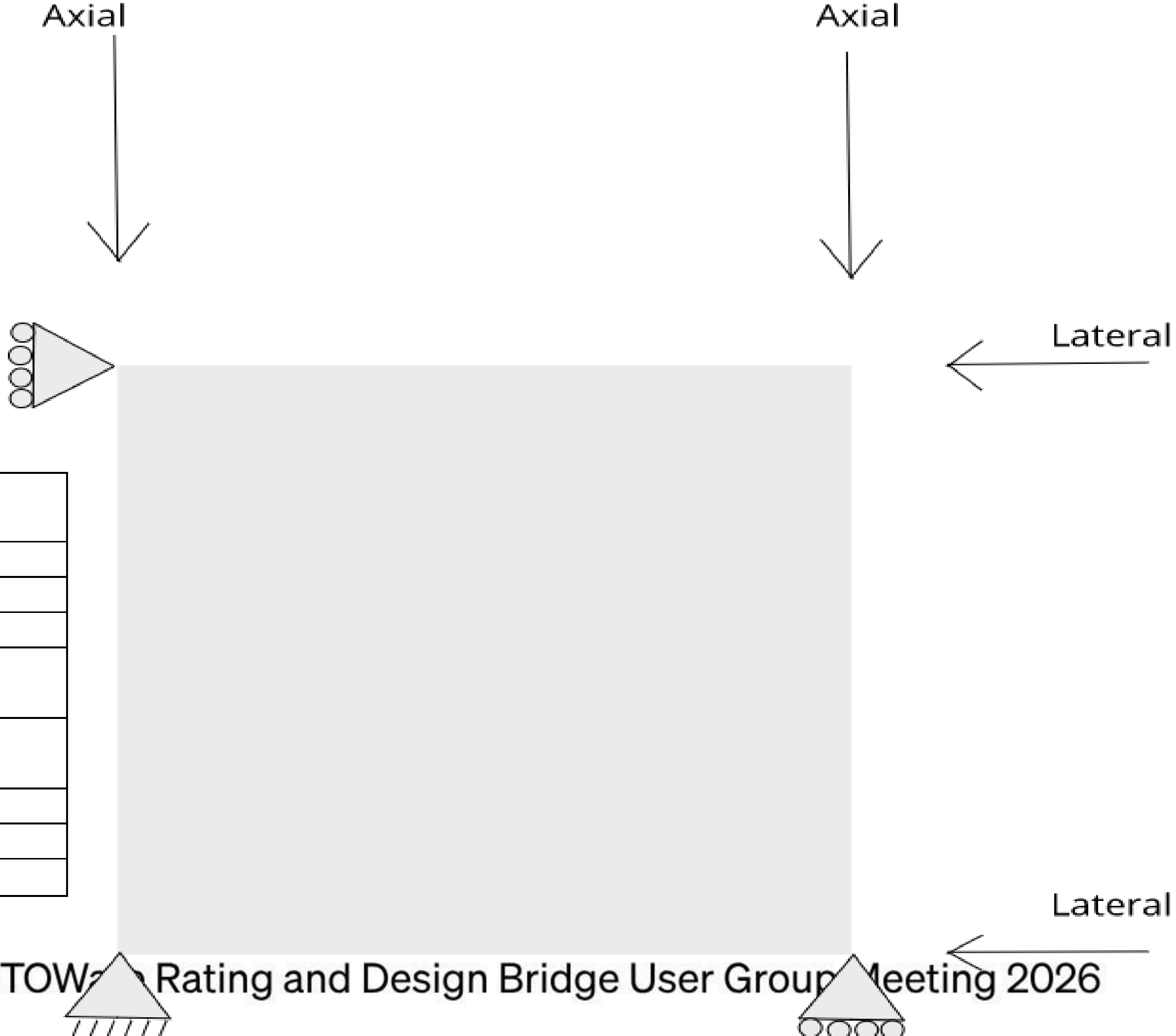


Table 3.8.2-2. Duncan/Selig 8 parameters for Cooks Bayou Sand.

Parameter Name	Symbols	Values based on best fit to data
Cohesion strength	c	12.5 psi
Internal friction angle	φ_0	35.6^0
Reduction of angle	$\Delta\varphi$	0.0
Magnitude of E_i	K	238 (atmospheres) KPa = 3500 psi
Exponent for E_i	n	0.0823 $E_i = 3500(\sigma_3/14.7)^{0.0823}$
Ratio of failure	R_f	0.80
Initial Bulk modulus	B_i	1263 psi (Bi/Pa = 85.92)
Ultimate vol. strain	ε_u	0.1177%

Phase 1

Culvert SSI Implementation Update-Validation

- Focused Element tests
- Duncan – Duncan/Selig Material Testing

			BrDR				CANDE		
Lateral	Axial		E_tangent	E_bulk	nu		E_tangent	E_bulk	nu
25	113		299.582	2396.65	0.479		299.58	2396.7	0.479
25	100		443.803	3550.43	0.479		443.8	3550.4	0.479
25	75		800.549	6404.39	0.479		800.55	6404.4	0.479
25	50		1261.76	9599.59	0.478		1261.8	9599.5	0.478
25	25		1827.45	9492.06	0.468		1827.4	9492	0.468

Culvert SSI Implementation Update- Validation

Global tests

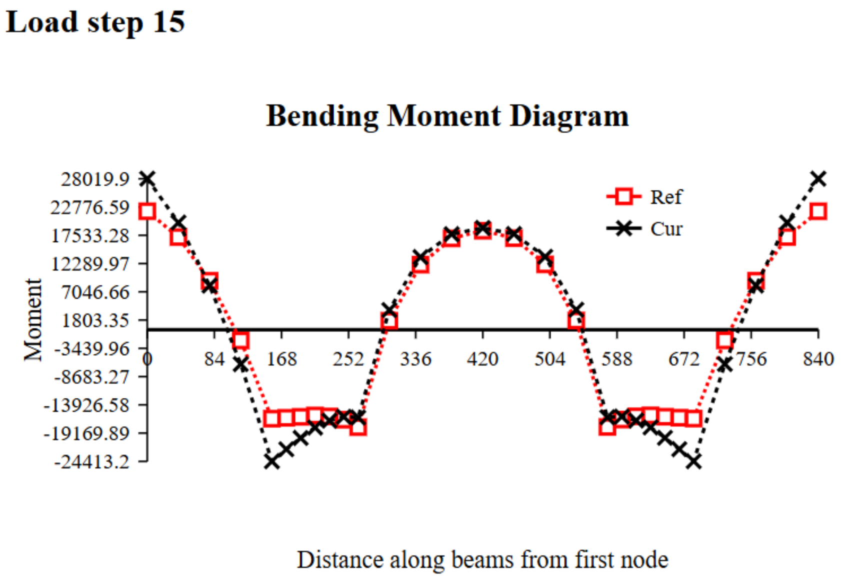
- Full CANDE models that run in both CANDE and BrDR
- CANDE *.cid files are imported into the AASHTO SSI engine
- Comparison tools written for the validation
- 10 models of varying soil models and structure types

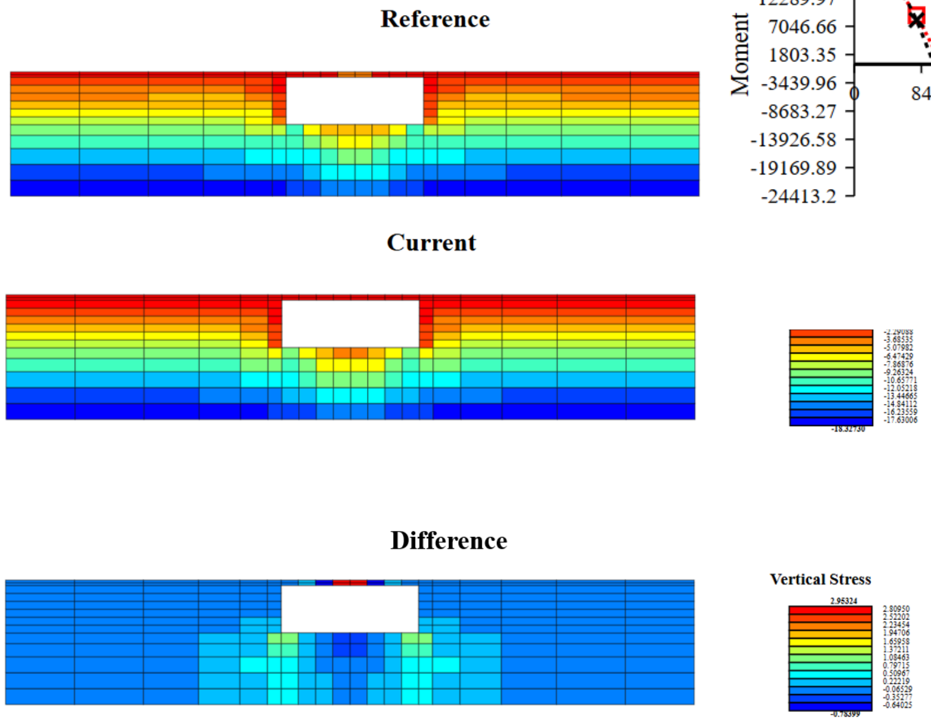
Culvert SSI Implementation Update- Validation

Phase 1

Global tests

- Validation tools – in place
- Can be used now and for future testing/ support





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ge User Group Meeting 2026

Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation

Implementation of the Concrete UI for SSI

- Mockups prepared (44 mockup pages for the RC Box)
- Reviewed by Culvert TAG
- Comments addressed
- Interface/DL implementation in Phase 2.1 – Year 1 (Version 7.9-in progress)
- LL implementation in Phase 2.1 – Year 2

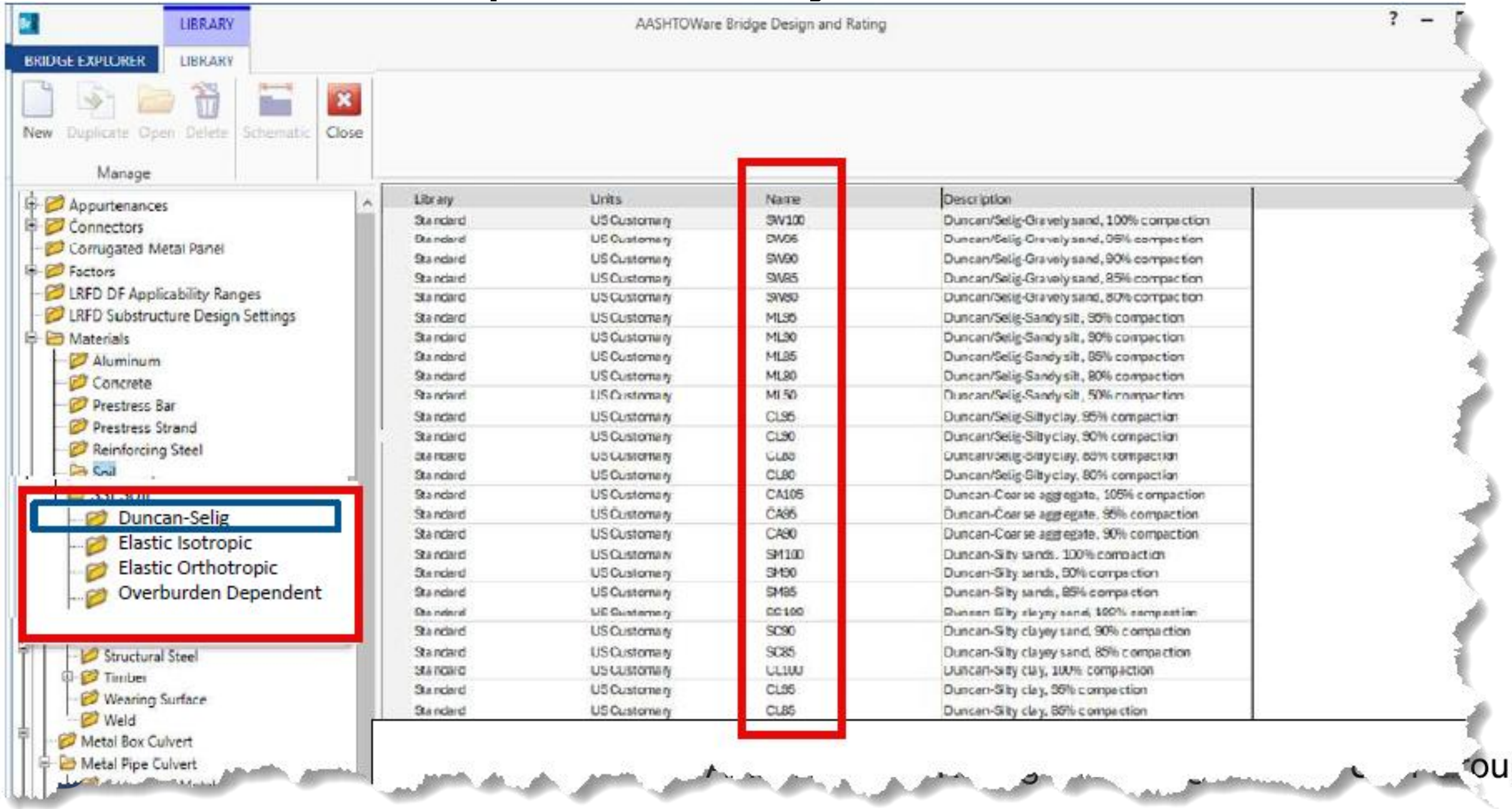
Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Implementation of the Concrete UI for SSI

- Maintain the existing concrete culvert definitions
- Add on to definitions with things that are needed for the SSI analysis
- Two methods of analysis
  - Existing AASHTO spec checking without SSI (line-girder)
  - New analysis with SSI (additional input required)

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – Library – new soil models

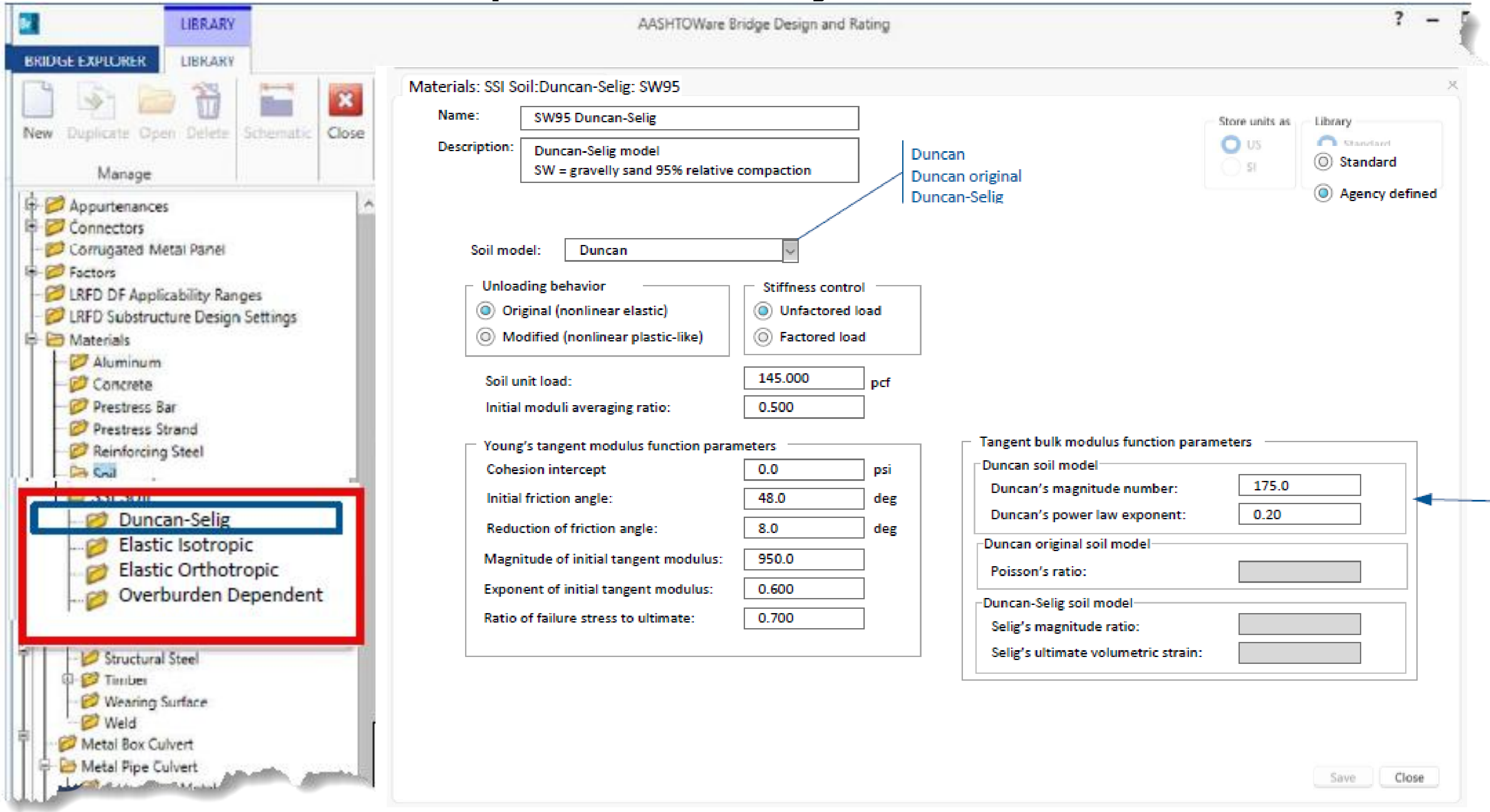


Library	Units	Name	Description
Standard	US Customary	SW100	Duncan/Selig-Gravely sand, 100% compaction
Standard	US Customary	SW95	Duncan/Selig-Gravely sand, 95% compaction
Standard	US Customary	SW90	Duncan/Selig-Gravely sand, 90% compaction
Standard	US Customary	SW85	Duncan/Selig-Gravely sand, 85% compaction
Standard	US Customary	SW80	Duncan/Selig-Gravely sand, 80% compaction
Standard	US Customary	ML95	Duncan/Selig-Sandy silt, 95% compaction
Standard	US Customary	ML90	Duncan/Selig-Sandy silt, 90% compaction
Standard	US Customary	ML85	Duncan/Selig-Sandy silt, 85% compaction
Standard	US Customary	ML80	Duncan/Selig-Sandy silt, 80% compaction
Standard	US Customary	ML50	Duncan/Selig-Sandy silt, 50% compaction
Standard	US Customary	CL95	Duncan/Selig-Silty clay, 95% compaction
Standard	US Customary	CL90	Duncan/Selig-Silty clay, 90% compaction
Standard	US Customary	CL85	Duncan/Selig-Silty clay, 85% compaction
Standard	US Customary	CL80	Duncan/Selig-Silty clay, 80% compaction
Standard	US Customary	CA105	Duncan-Coarse aggregate, 105% compaction
Standard	US Customary	CA95	Duncan-Coarse aggregate, 95% compaction
Standard	US Customary	CA90	Duncan-Coarse aggregate, 90% compaction
Standard	US Customary	SM100	Duncan-Silty sands, 100% compaction
Standard	US Customary	SM90	Duncan-Silty sands, 90% compaction
Standard	US Customary	SM85	Duncan-Silty sands, 85% compaction
Standard	US Customary	SC100	Duncan-Silty clayey sand, 100% compaction
Standard	US Customary	SC90	Duncan-Silty clayey sand, 90% compaction
Standard	US Customary	SC85	Duncan-Silty clayey sand, 85% compaction
Standard	US Customary	CL100	Duncan-Silty clay, 100% compaction
Standard	US Customary	CL95	Duncan-Silty clay, 95% compaction
Standard	US Customary	CL85	Duncan-Silty clay, 85% compaction

Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – Library – new soil models



Only enable the group box for the selected Soil Model.

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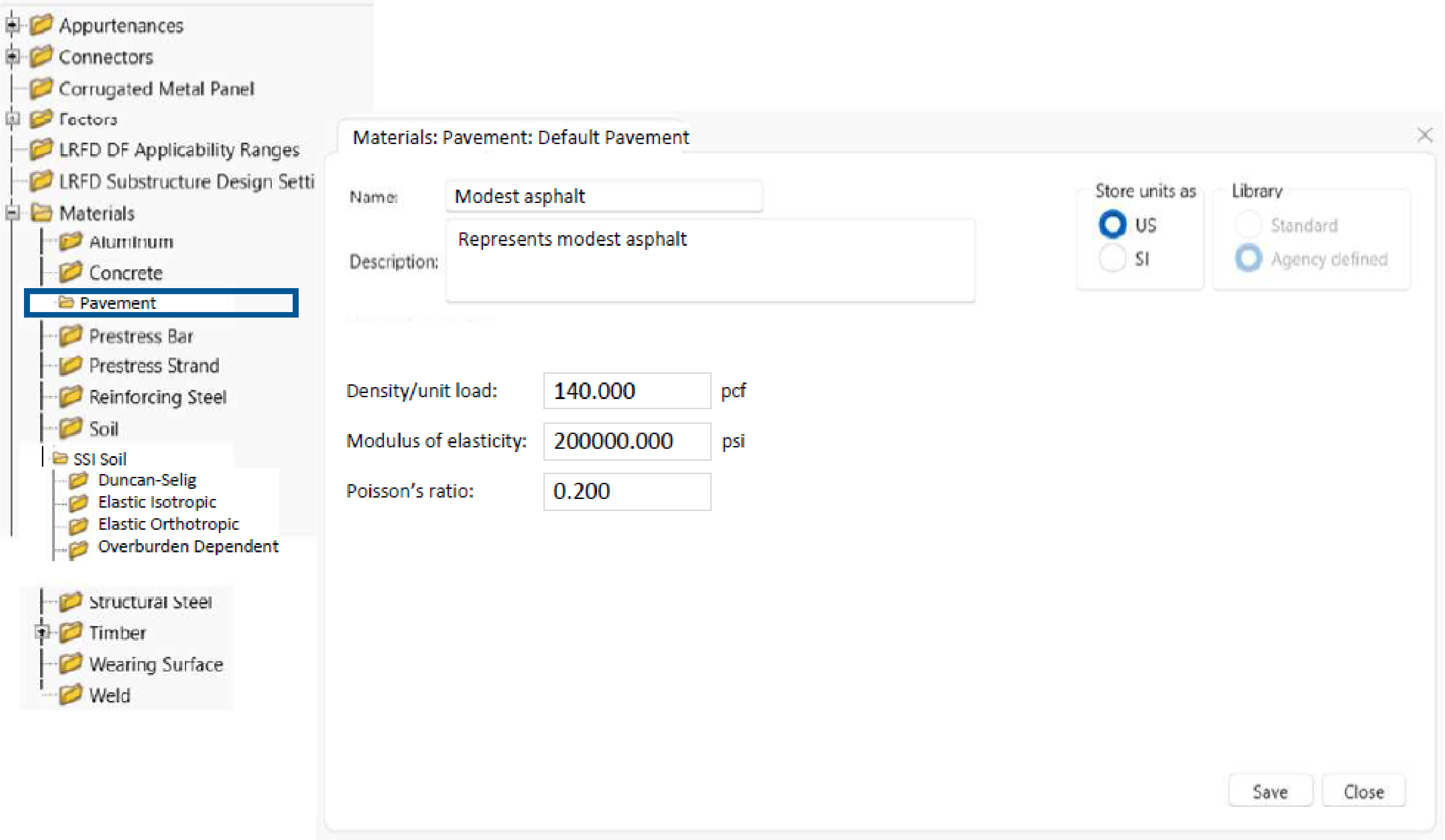
Phase 2.1

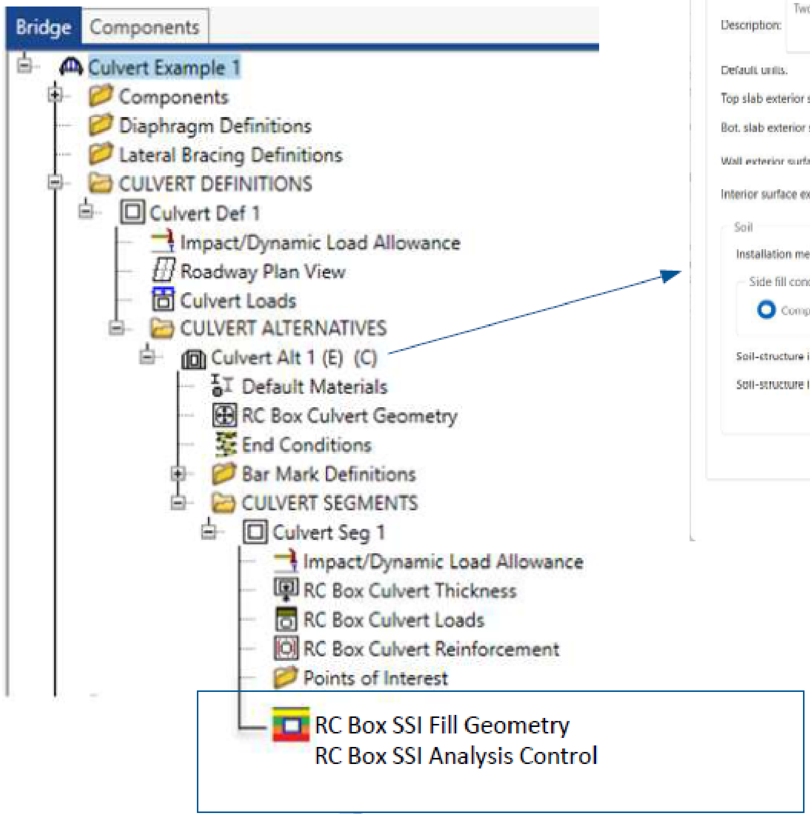
Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

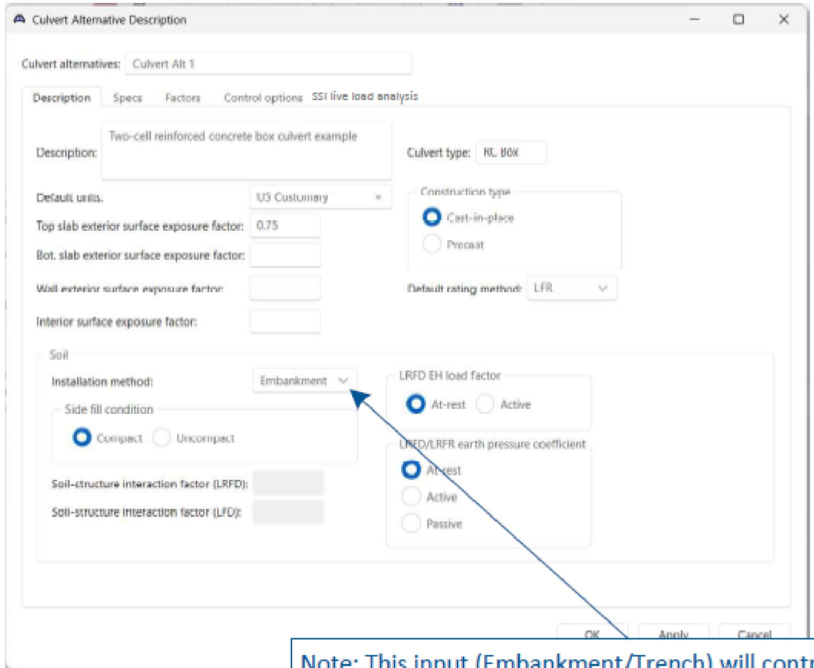
Samples from the mockups – Library – Pavement



Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – BWS – New RC windows





Note: This input (Embankment/Trench) will control the content on the subsequent SSI Fill Geometry window. If user re-opens this window, changes this selection from Trench to Embankment and clicks OK/Apply, issue warning message:
"Warning: Changing the installation method will delete trench data on the SSI Fill Geometry window. Do you want to continue? Yes/No"
Do not allow changing of this field while the RC Box SSI Fill Geometry window is open.

Two new windows for RC Box culverts. No data on these SSI windows needs to be input to continue to analyze the culvert using the 'line-girder' method. This input is only needed if an SSI analysis is to be performed.

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Phase 2.1

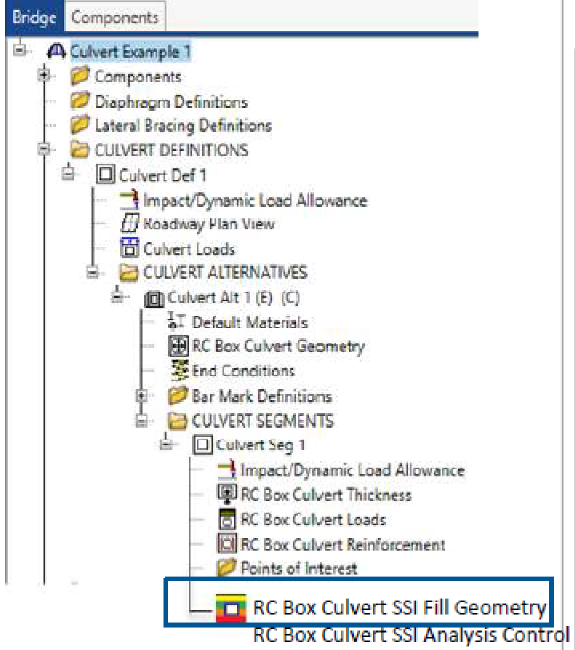
Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – BWS – New RC windows-Fill Geometry

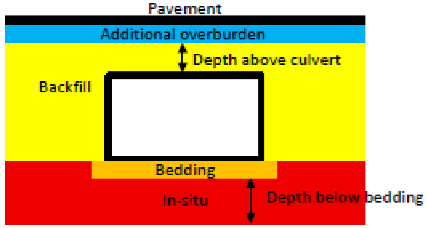
Embankment

Constant fill depth

RC Box Culvert SSI Fill Geometry: Embankment



Figures similar to the following will be shown in the Help to describe the soil layers for both the embankment and trench installations



RC Box Culvert SSI Fill Geometry

Installation method: Embankment (1)

☐ Consider in-situ soil self weight deformation (2)

Pavement
☑ Consider pavement for rating (3)
Material: Pavement
Thickness: 12.0 in

Elastic wearing course
☐ Consider elastic wearing course for design
☐ Consider elastic wearing course for rating (3)
Modulus of elasticity: ksi
Poisson's ratio: (4)

Pavement loading will always consider the DW load factor.
Drop-down selections include:
all SSI Pavements in the BWS,
-None-
-Create new material-

☐ Varying backfill depth above culvert (5)

Depth of fill at start edge: ft
Depth of fill at end edge: ft

Pavement and Elastic group boxes are always enabled. Pavement and Elastic can both be used at the same time.

Soil area	Depth (ft)	SSI soil
Additional overburden		Soil 123
Backfill (depth above culvert)		CL95
Bedding		CL95
In-situ (depth below bedding)		CL95

Drop-down selections include:
all SSI Soils in the BWS,
-Create new Duncan-Selig-
-Create new Elastic Isotropic-
-Create new Elastic Orthotropic-
-Create new Overburden Dependent-

Bedding left extension: 1.00 ft
Bedding right extension: 1.00 ft

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Phase 2.1

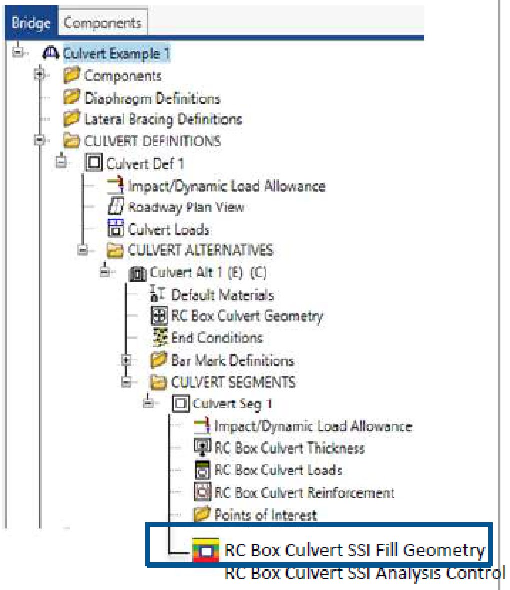
Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

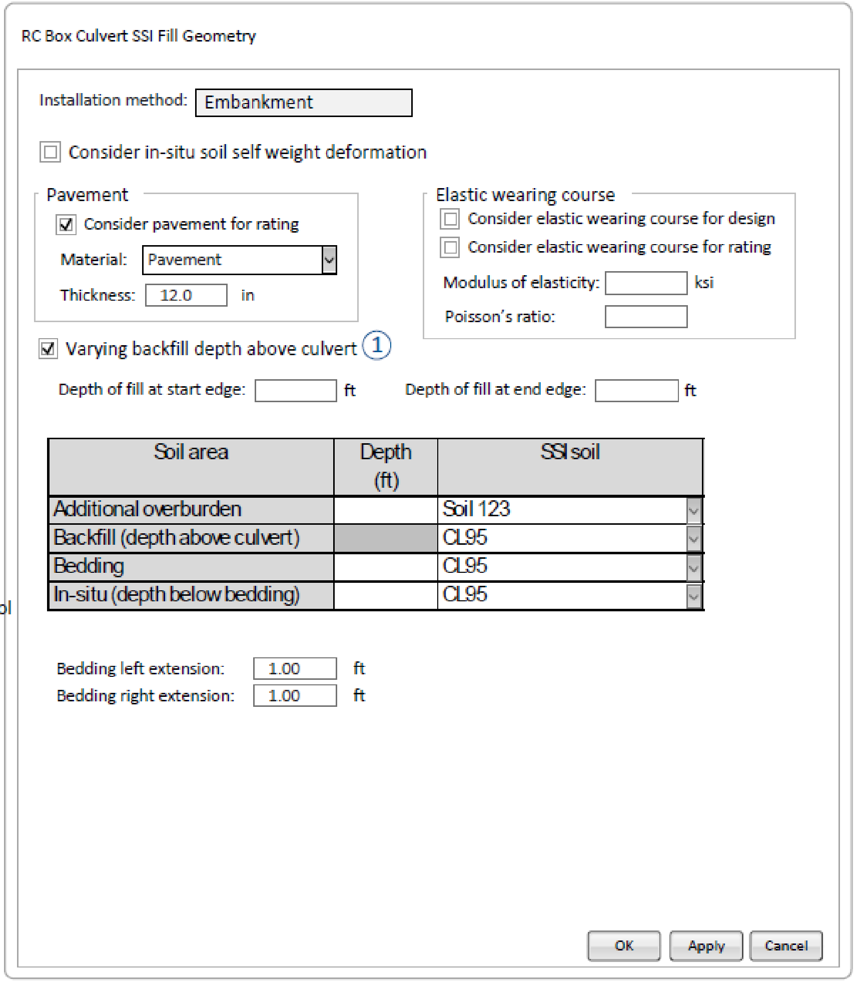
Samples from the mockups – BWS – New RC windows-Fill Geometry

Embankment

Varying fill depth

RC Box Culvert SSI Fill Geometry: Varying Embankment




RC Box Culvert SSI Fill Geometry

Installation method: Embankment

☐ Consider in-situ soil self weight deformation

Pavement

☑ Consider pavement for rating

Material: Pavement

Thickness: 12.0 in

Elastic wearing course

☐ Consider elastic wearing course for design

☐ Consider elastic wearing course for rating

Modulus of elasticity: ksi

Poisson's ratio:

☑ Varying backfill depth above culvert (1)

Depth of fill at start edge: ft   Depth of fill at end edge: ft

Soil area	Depth (ft)	SSI soil
Additional overburden		Soil 123
Backfill (depth above culvert)		CL95
Bedding		CL95
In-situ (depth below bedding)		CL95

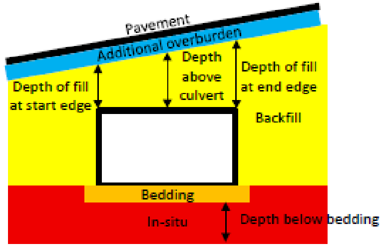
Bedding left extension: 1.00 ft

Bedding right extension: 1.00 ft

OK Apply Cancel

(1) Default is not checked. Checking this box will enable start and end depth edit controls and disable the Depth cell in the grid.

Figures similar to the following will be shown in the Help to describe the soil layers for both the embankment and trench installations



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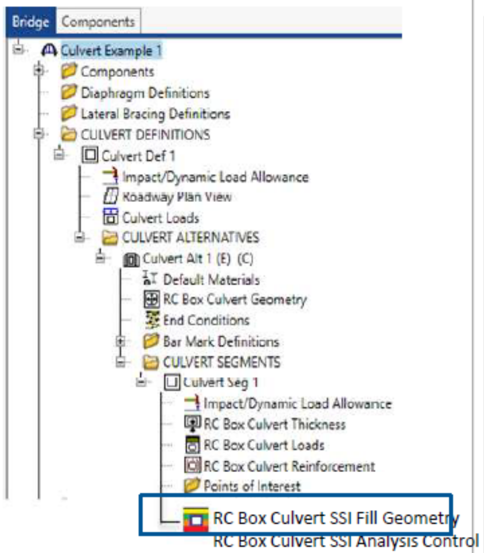
Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

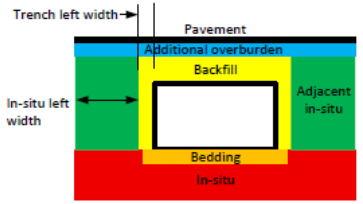
Samples from the mockups – BWS – New RC windows- Fill Geometry

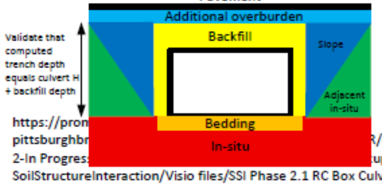
Trench (not sloped or sloped)

RC Box Culvert SSI Fill Geometry: Trench

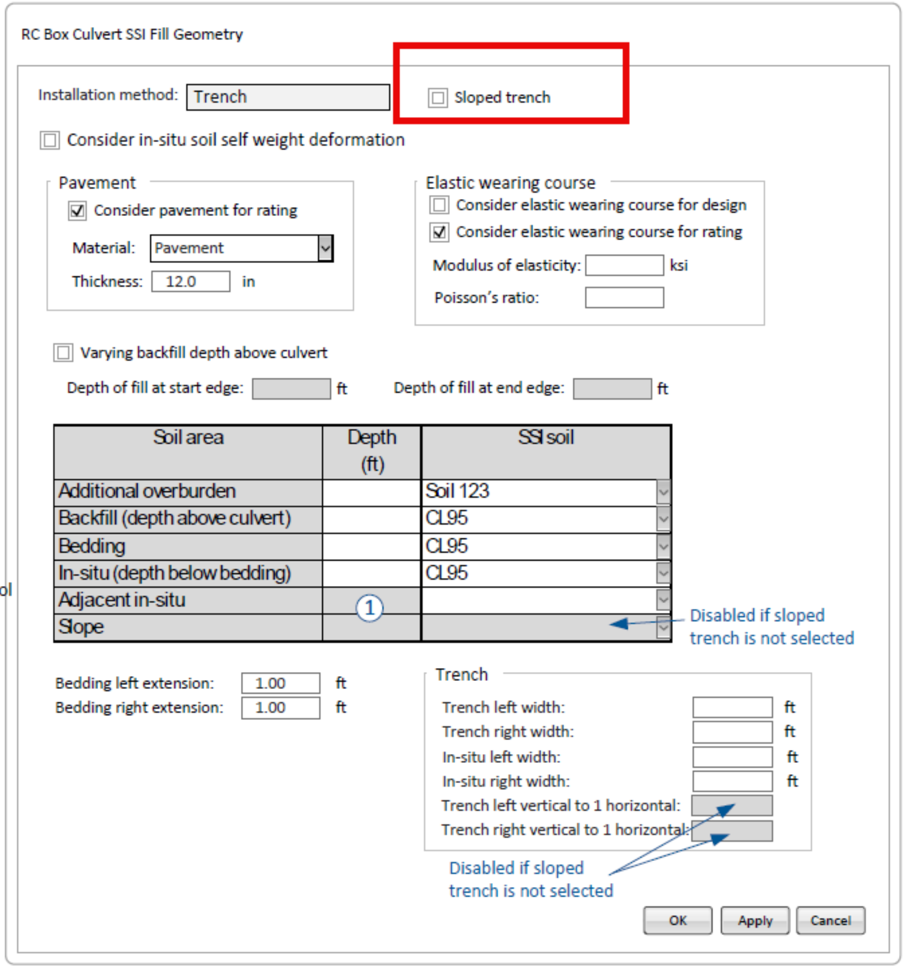


Figures similar to the following will be shown in the Help to describe the soil layers for both the embankment and trench installations





https://pron... pittsburghbr... R/Planning/ 2-In Progres... ups- SoilStructureInteraction/Visio files/SSI Phase 2.1 RC Box Culvert



(1) Adjacent in-situ and Slope Depth cells are always disabled since the trench depth is determined by the depth above culvert value. Validation will check that the trench depth computed using the depth above culvert value matches the value computed using the in-situ width and slope for a sloped trench.

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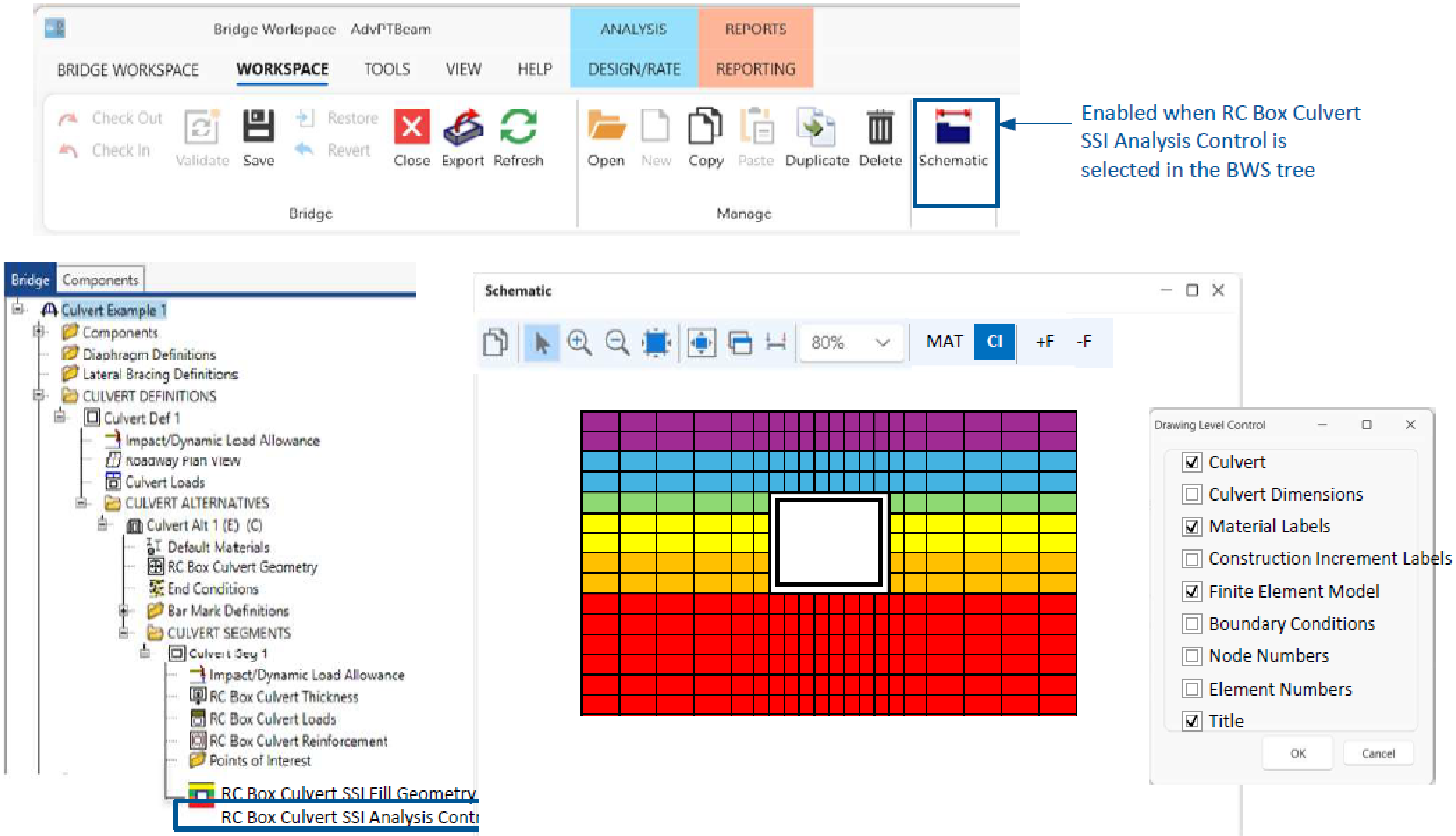
Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – BWS – New RC windows- Analysis Control Schematic

RC Box Culvert SSI Analysis Control Schematic



The FE mesh will be generated when this schematic is opened and user can turn its display on/ off.

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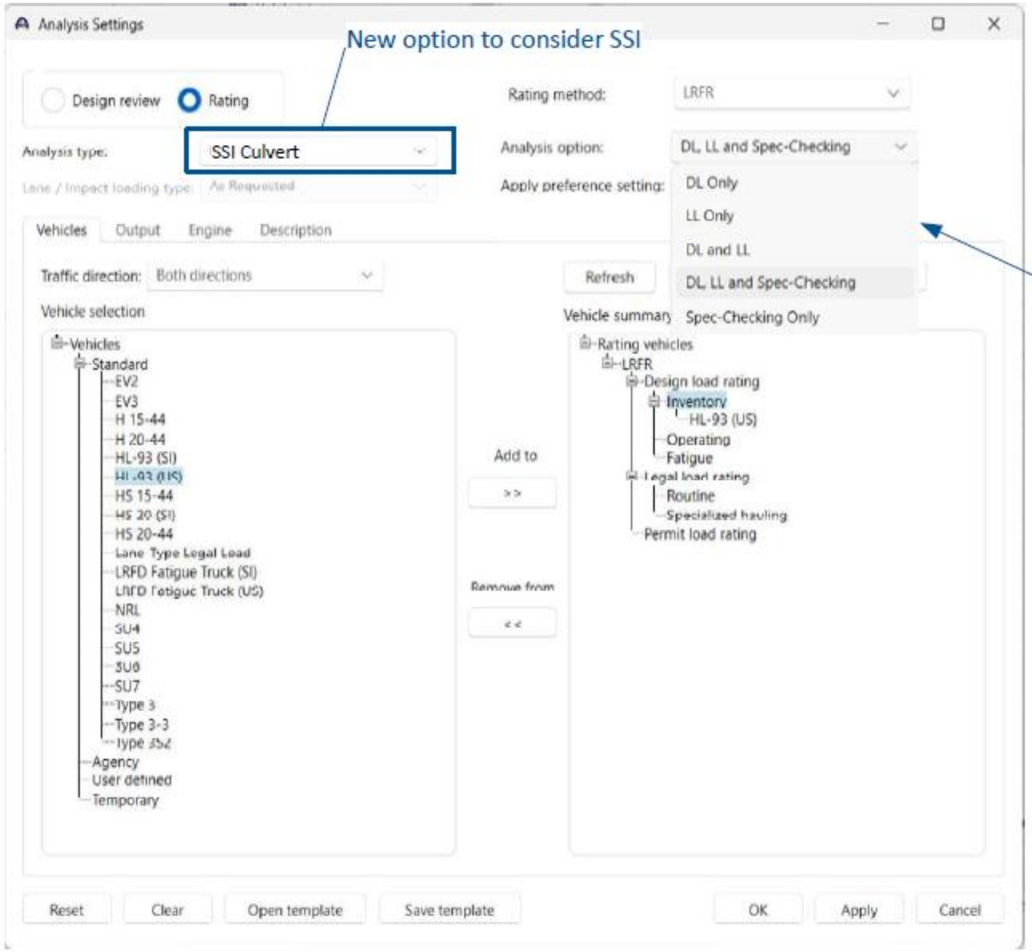
Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – BWS – New RC windows- Analysis Settings

Analysis Settings SSI



Supported analysis:
- LRFD (Design Review)
- LRFR (Rating)

LL Only is not supported as DL effects are required in an SSI LL analysis

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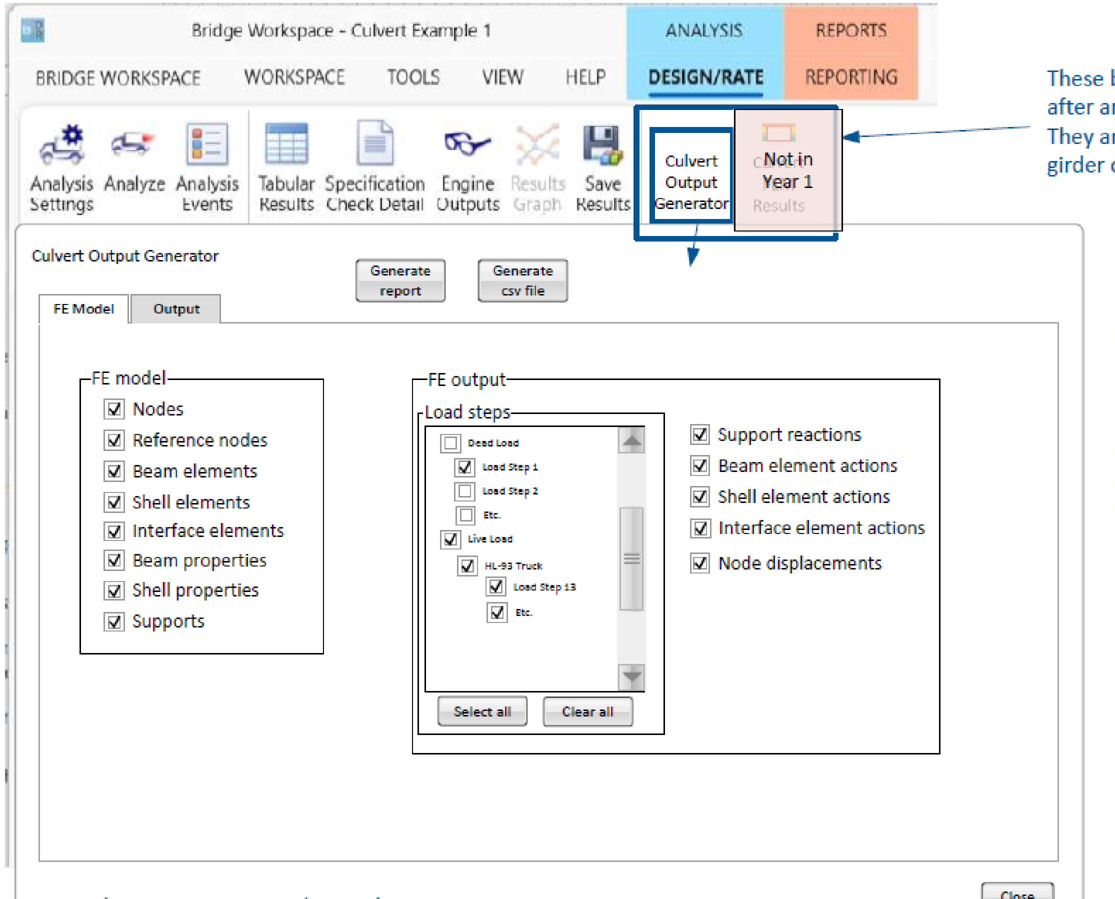
Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – BWS – New RC windows-Engine Output Generator

Results - Engine Output Generator



These buttons are enabled after an SSI culvert analysis. They are not enabled for a line girder culvert analysis.

Clicking the Generate report button will create the report and open a window to view the report.
Clicking the Generate csv file will create the csv file and open a dialog to save the csv file.

This is a new page in the mockups.
Due to the amount of output available in an SSI analysis, the user can choose what data to report.
User can select to generate a report for the report viewer and/or csv files.
These reports are in xml format or csv format.

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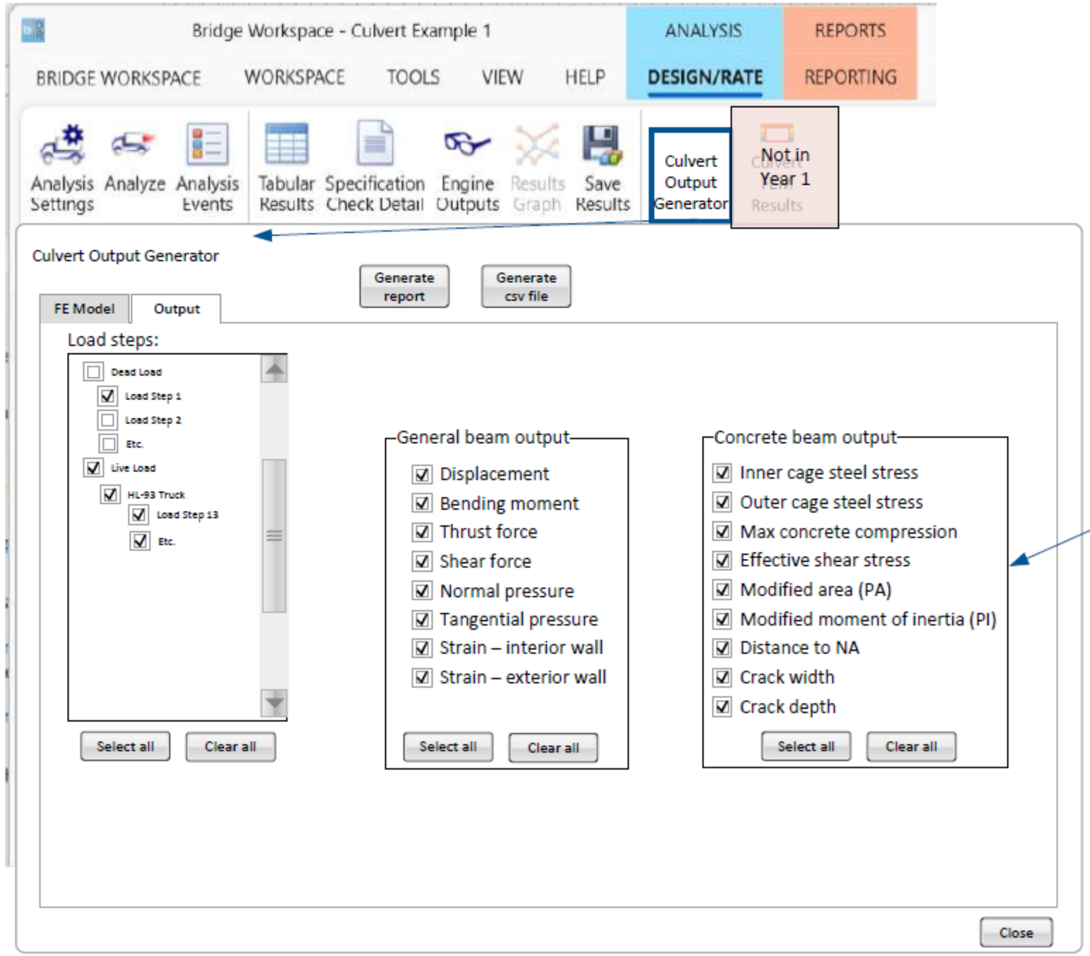
Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 1

Samples from the mockups – BWS – New RC windows-Engine Output Generator

Results - Engine Output Generator cont'd



Clicking the Generate report button will create the report and open a window to view the report.
Clicking the Generate csv file will create the csv file and open a dialog to save the csv file.

If a metal SSI culvert is analyzed, this box will display the output available for metal boxes.

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Phase 2.1

Culvert SSI Implementation – Concrete Interface – Engine Implementation-Year 2

Concrete Interface – Year 2

- LL results
- Results Graph
- FEM Results (mesh stress/strain plotting)
- Spec checking (with SSI results)
- Validation examples/testing

Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Metal Culvert Interface

- Similar process for the interface mockup and approval
- This will begin in Phase 2.2
- This will be a new structure type

Phase 2.2

Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Metal Culvert Interface – Mockup samples

Metal Pipe Culvert. Structural Plate Pipe. 6 x 2 Stl. structural plate pipe

Name: 6 x 2 Stl. structural plate pipe

Description: Mp value assumes Fy = 34 ksi as per "Design Procedures for Flexible Metal Culvert Structures" by Duncan & Drawsky, May 1983

New description for this steel plate item

Store units as: US / SI

Library: Standard / Agency defined

Culvert type: Structural plate pipe

Material: Steel / Aluminum

Seam type: Bolted

	Section Properties						Seam Strength					
Gage	Thickness (in)	A (in^2/ft)	r (in)	I (in^4/in x 10^-3)	S (in^3/ft)	Mp kip-ft/ft)	Bolt diameter (in)	4 bolts/foot (kip/ft)	5 1/3 steel bolts/foot (kip/ft)	5 1/3 alum. bolts/foot (kip/ft)	6 bolts/foot (kip/ft)	8 bolts/foot (kip/ft)
12	0.109	1.556	0.682	60.[illegible]1		2.660	0.750	43.00				
10	0.130	2.003	0.684	70.[illegible]5		3.440	0.750	62.00				
8	0.168	2.449	0.686	96.[illegible]3		4.220	0.750	81.00				
7	0.188	2.739	0.688	108.[illegible]0		4.730	0.750	93.00				
5	0.218	3.199	0.690	126.[illegible]2		5.540	0.750	112.00				
3	0.249	3.650	0.692	146.[illegible]2		6.360	0.750	132.00				
1	0.280	4.119	0.695	165.[illegible]6		7.180	0.750	144.00			180.00	194.00
	0.318	4.671	0.698	190.[illegible]0			0.875					235.00

New Duplicate Delete

Add column for section modulus S.

Save Close

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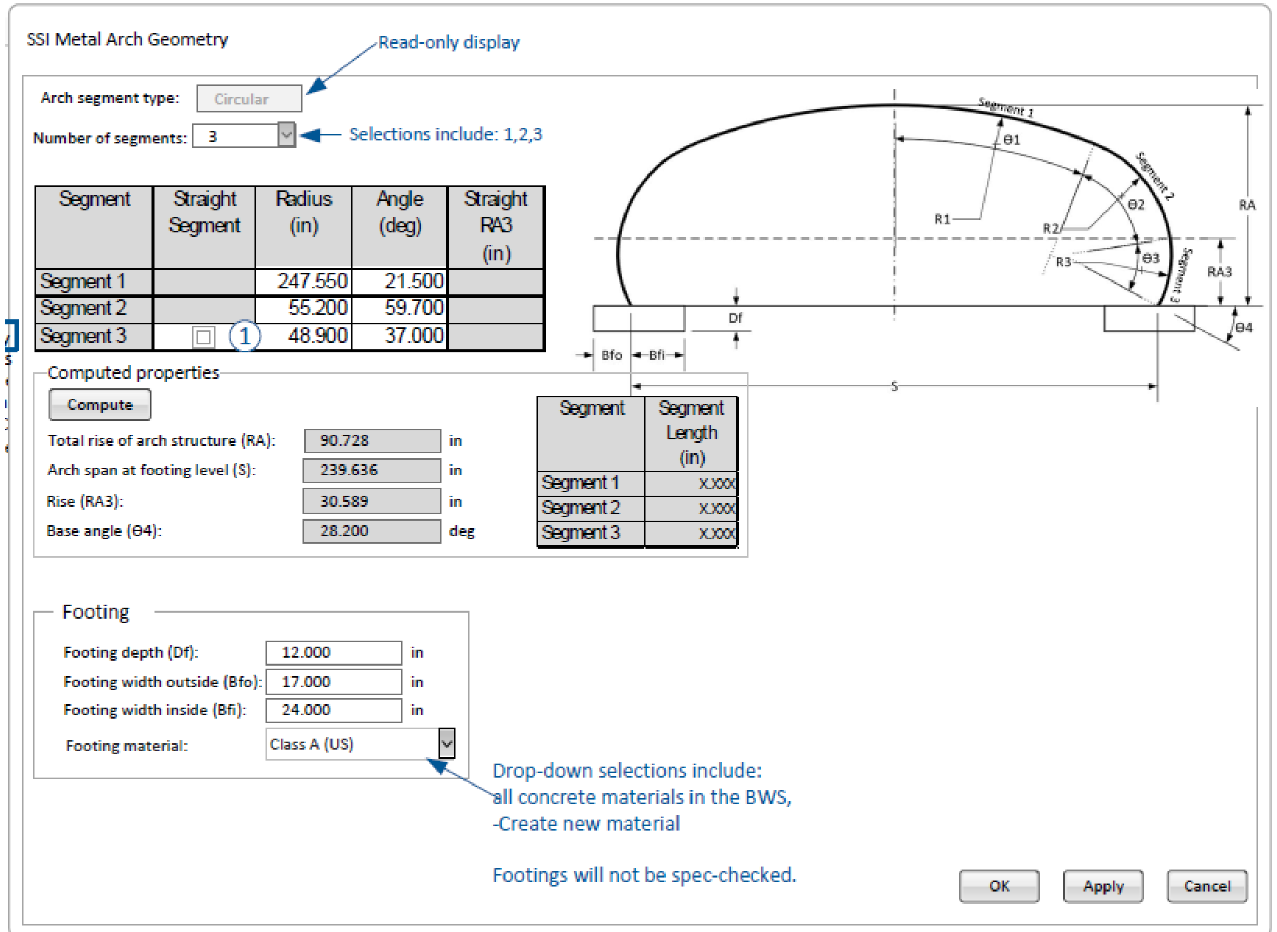
Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Metal Culvert Interface – Mockup samples – Different geometry

- Multiple segments
- Up to 3



SSI Metal Arch Geometry

Read-only display

Arch segment type: Circular

Number of segments: 3

Selections include: 1,2,3

Segment	Straight Segment	Radius (in)	Angle (deg)	Straight RA3 (in)
Segment 1		247.550	21.500	
Segment 2		55.200	59.700	
Segment 3	☐ 1	48.900	37.000	

Computed properties

Compute

Total rise of arch structure (RA): 90.728 in

Arch span at footing level (S): 239.636 in

Rise (RA3): 30.589 in

Base angle (Θ4): 28.200 deg

Segment	Segment Length (in)
Segment 1	x.xxx
Segment 2	x.xxx
Segment 3	x.xxx

Footing

Footing depth (Df): 12.000 in

Footing width outside (Bfo): 17.000 in

Footing width inside (Bfi): 24.000 in

Footing material: Class A (US)

Drop-down selections include:
all concrete materials in the BWS,
-Create new material

Footings will not be spec-checked.

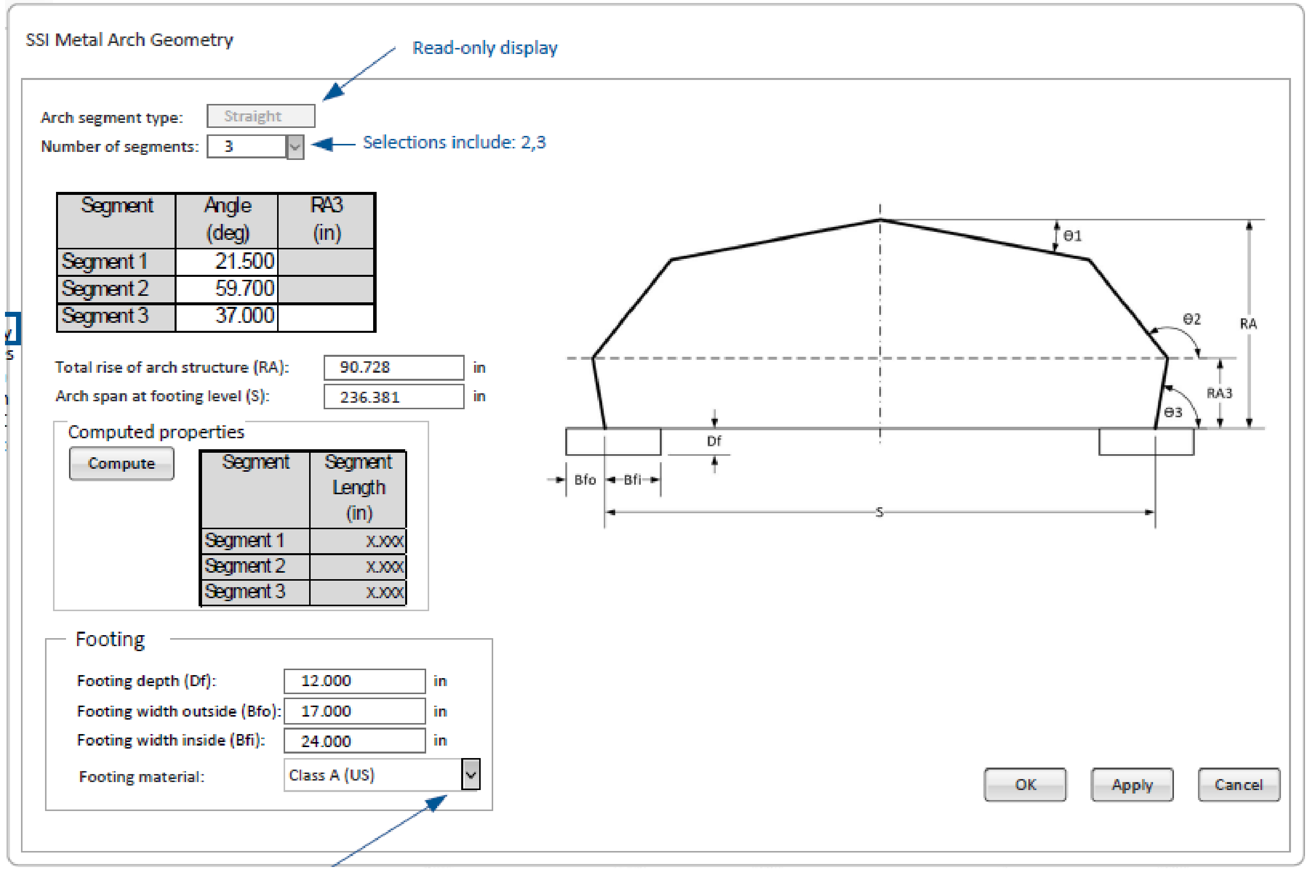
OK Apply Cancel

Phase 2.2

Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Metal Culvert Interface – Mockup samples – Different geometry

- Straight sided option



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Phase 2.2

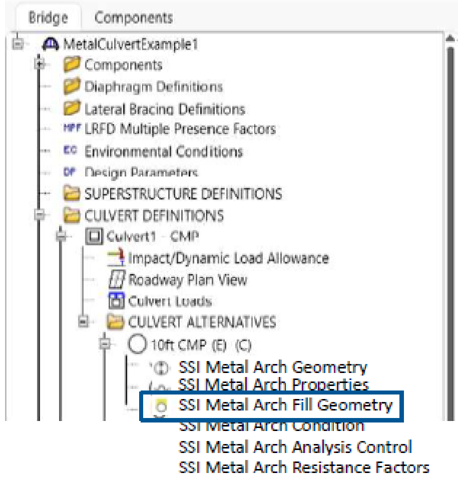
Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Metal Culvert Interface – Mockup samples – Different geometry

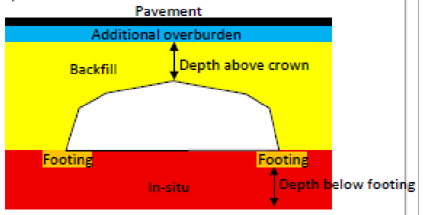
- Fill geometry options

- Similar to concrete

SSI Metal Arch Fill Geometry : Embankment



Figures similar to the following will be shown in the Help to describe the soil layers for both the embankment and trench installations



SSI Metal Arch Fill Geometry

Fill | Relieving slab

Installation method: Embankment (1)

Drop-down selections include:
all SSI Pavements in the BWS,
-None-
-Create new material-

☐ Consider in-situ soil self weight deformation (2)

Pavement
☑ Consider pavement for rating (3)
Material: Pavement
Thickness: 12.0 in

Elastic wearing course
☐ Consider elastic wearing course for design
☐ Consider elastic wearing course for rating (3)
Modulus of elasticity: ksi
Poisson's ratio: (4)

Pavement and Elastic group boxes are always enabled. Pavement and Elastic can both be used at the same time.

☐ Varying backfill depth above culvert (5)
Depth of fill at start edge: ft
Depth of fill at end edge: ft

Soil area	Depth (ft)	SSI soil
Additional overburden		Soil 123
Backfill (depth above crown)		CL95
In-situ (depth below footing)		CL95

Drop-down selections include:
all SSI Soils in the BWS,
-Create new Duncan-Selig-
-Create new Elastic Isotropic-
-Create new Elastic Orthotropic-
-Create new Overburden Dependent-

Deep corrugated
Ms, secant constrained soil modulus: ksi

This is enabled if the culvert alt type is deep corrugated. It is used for global buckling. See next page for more info.

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Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Metal Culvert Interface – Mockup samples – Different geometry

- Condition information – deterioration/deformation

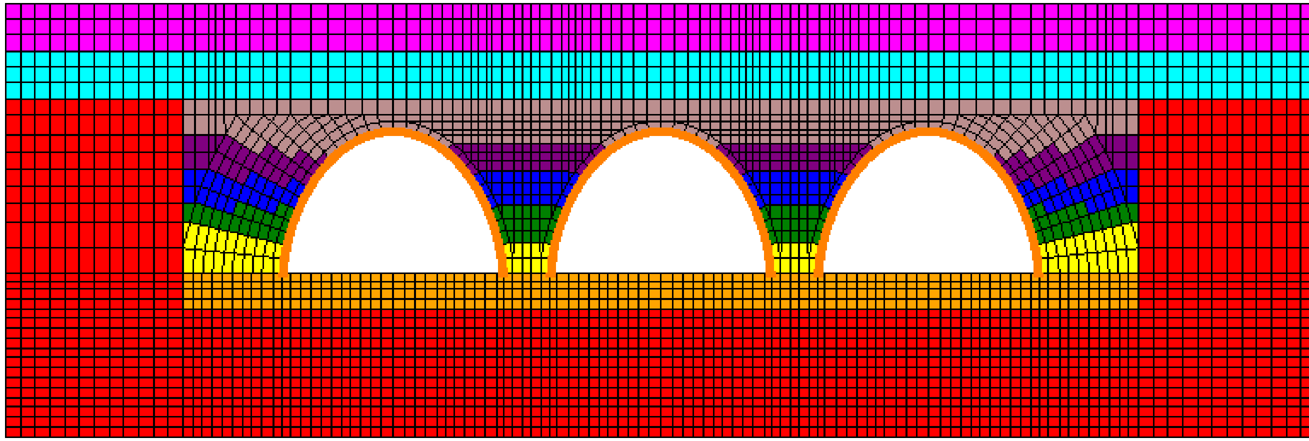
- Mockups still currently in draft form

Phase 3

Culvert SSI Implementation –Metal Culvert Interface – Engine Implementation

Phase 3 and beyond

- Produce models for more complicated structures
- Multiple pipes
- Multiple materials
- Different methods for LL analysis
- Guided by the needs of the agencies



Questions/Comments

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