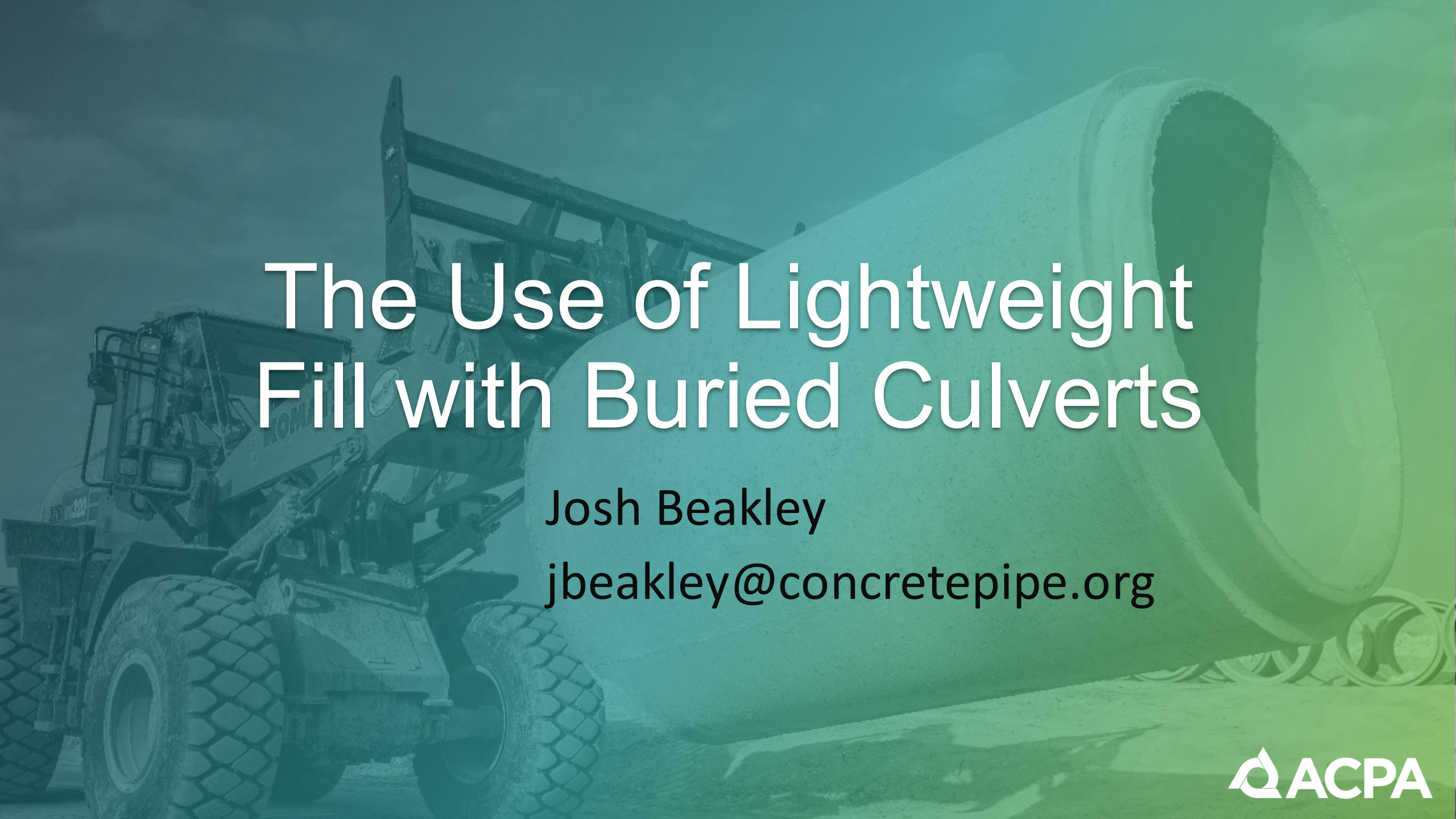


The Use of Lightweight Fill with Buried Culverts

Josh Beakley

jbeakley@concretepipe.org

ACPA



Become a member of ASTM C13, F36, and/or E60

C13 – Concrete Pipe

F36 – Technology and Underground Utilities

E60 - Sustainability

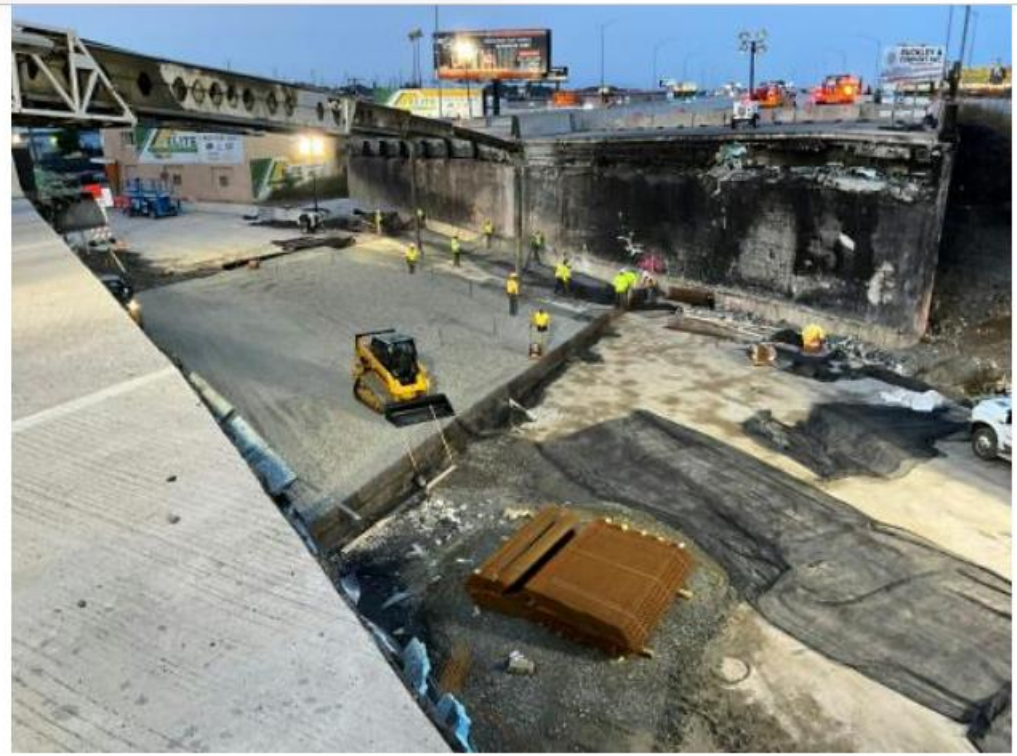
CONCRETE UNDERGROUND

September, 14–16
Frankfurt Region, Germany

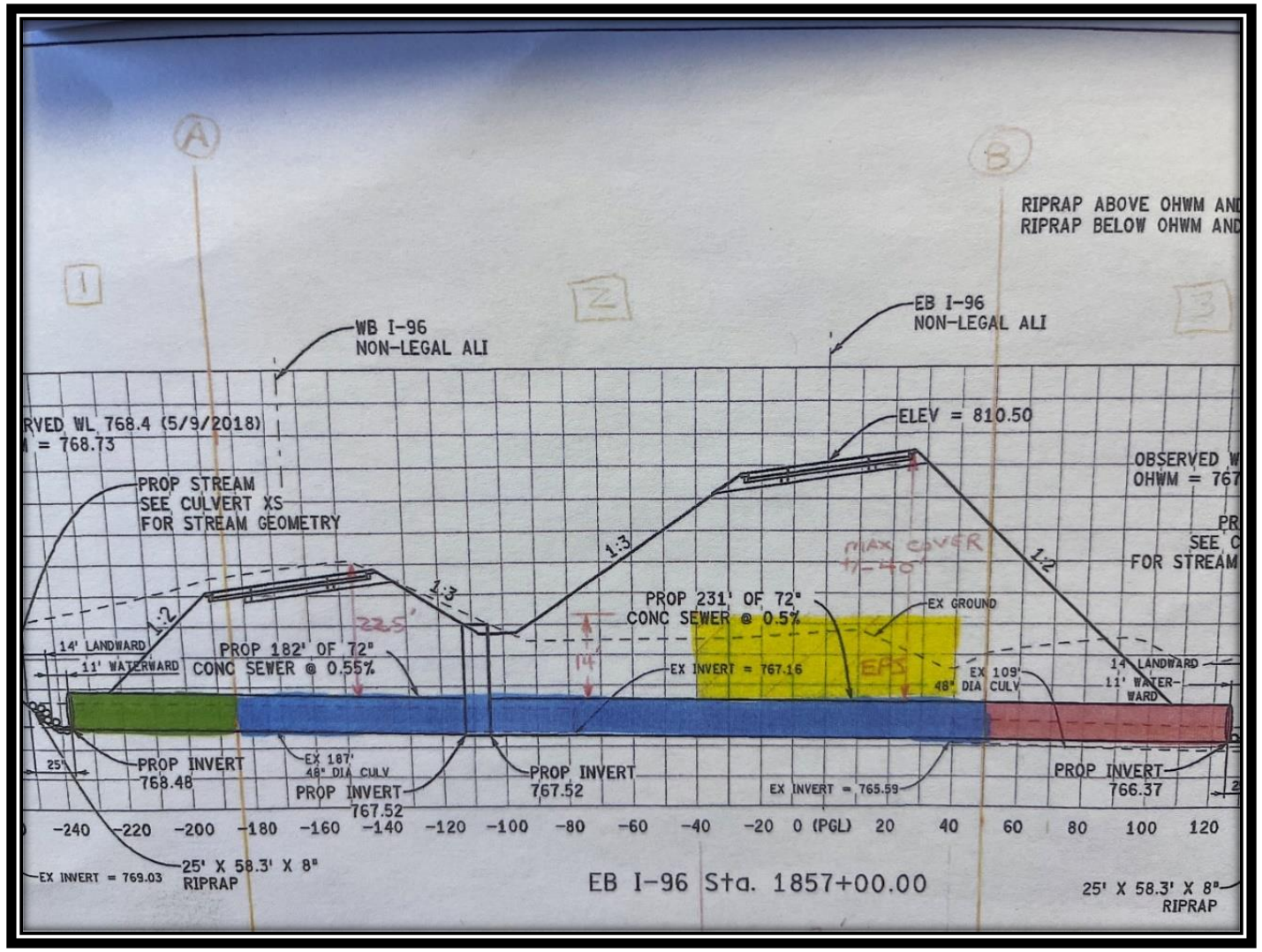


ACPA

PennDOT restores I-95 Overpass Collapse in 12-days with the help of Ultra-Lightweight Foamed Glass Aggregate

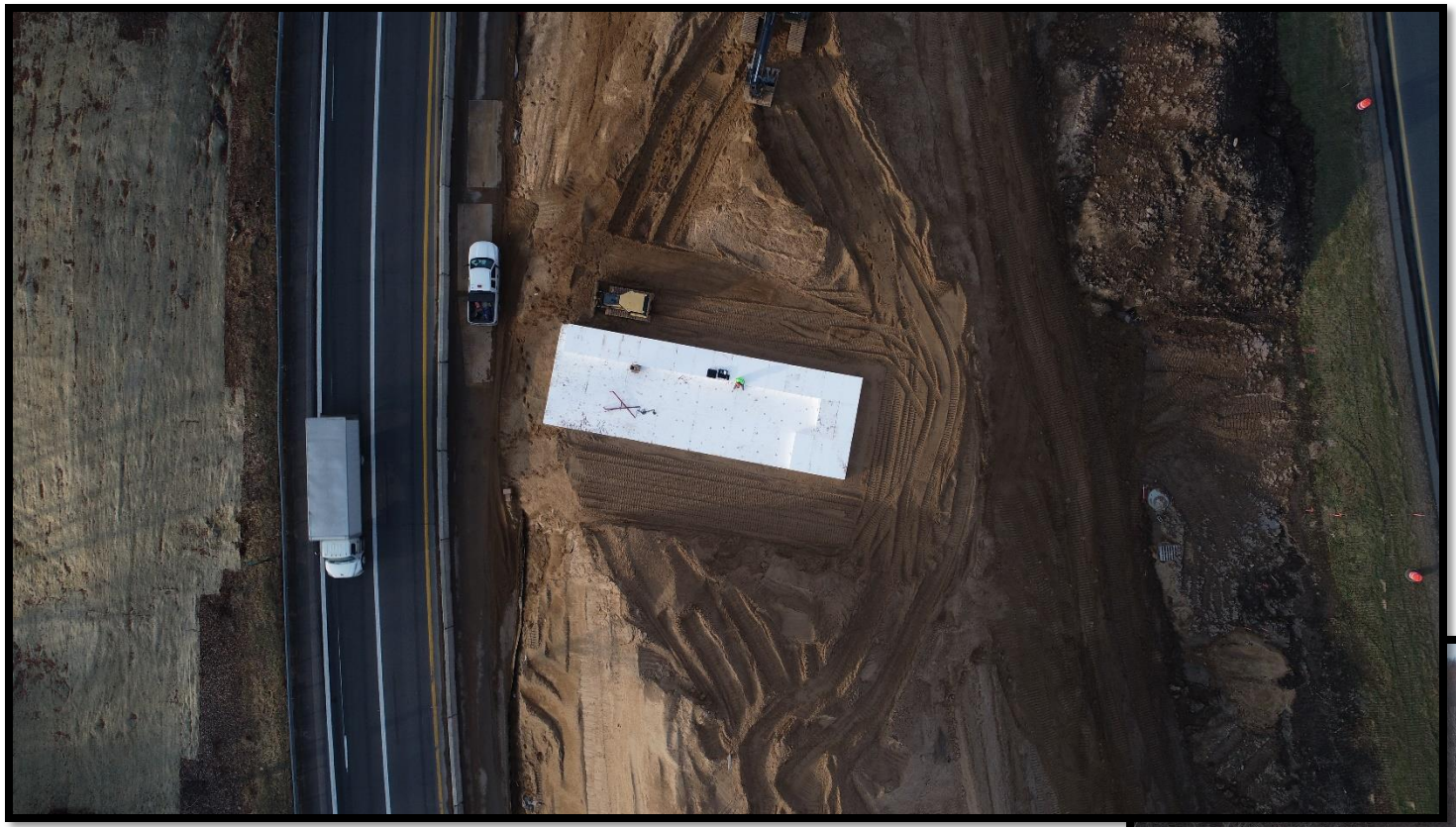


Crews work around the clock to complete the I-95 rebuild under an expedited timeline, using foamed glass aggregate from Aero Aggregates.



I96/I196 Interchange
Michigan DOT
2022 ACPA PAA Winner

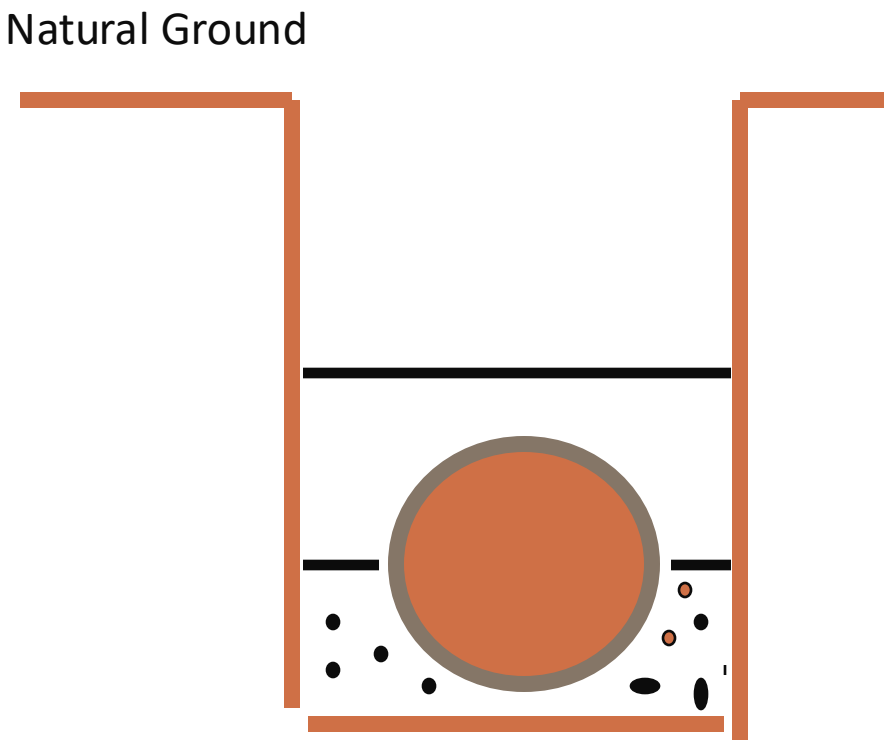
ACPA



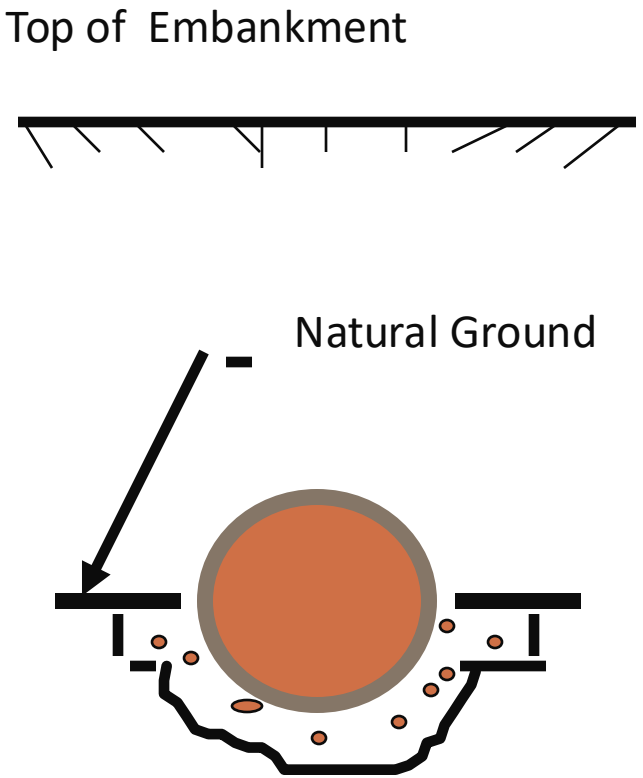
I96/I196 Interchange
Michigan DOT
2022 ACPA PAA Winner



Basic Methods of Installation

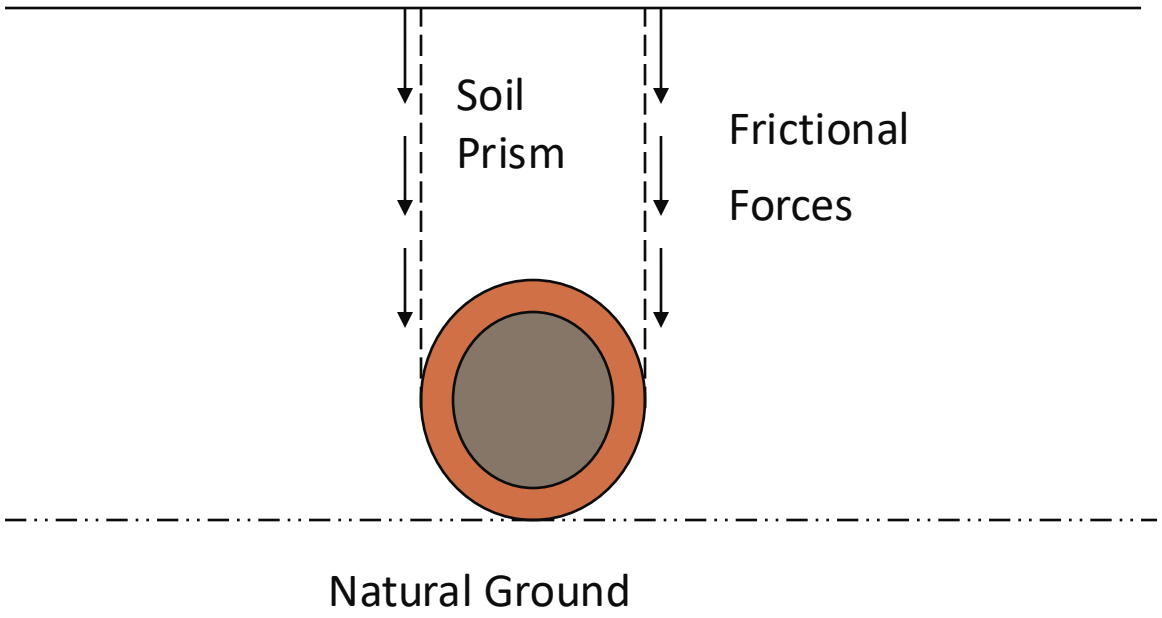


TRENCH



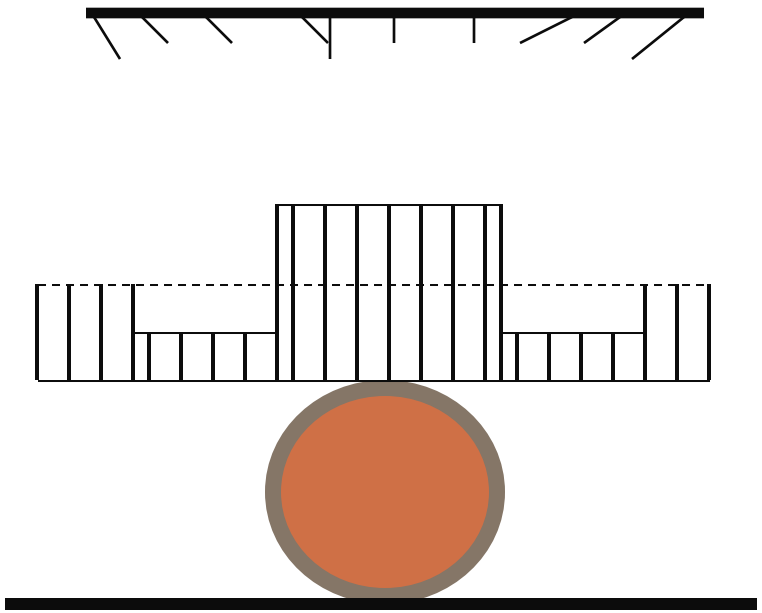
EMBANKMENT

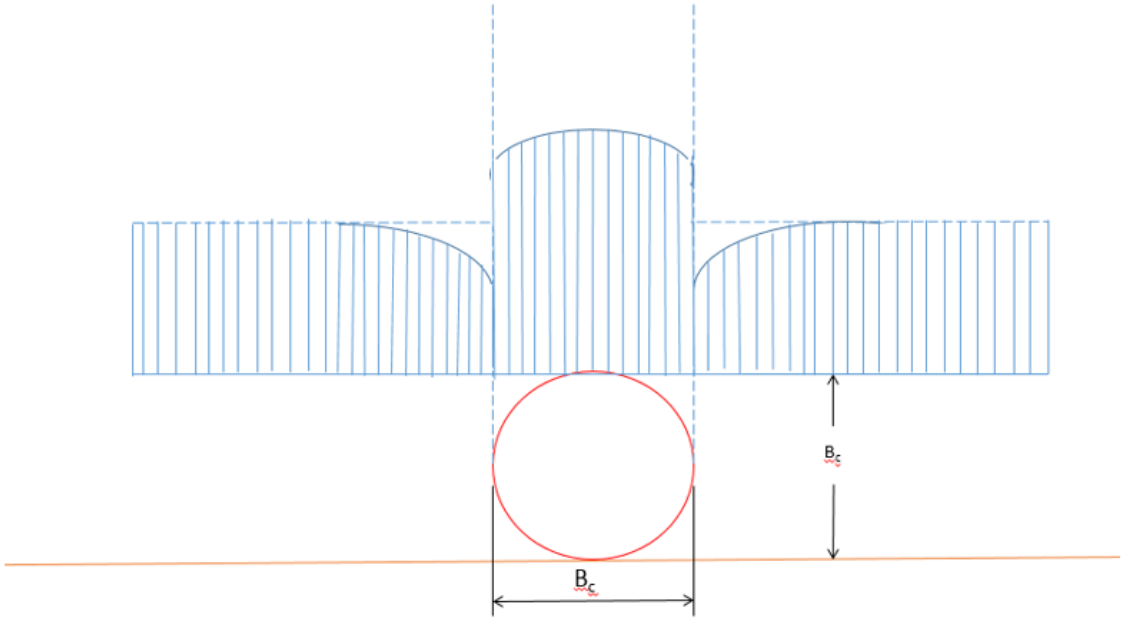
Positive Projecting Embankment Installation



Positive Projecting Embankment Condition

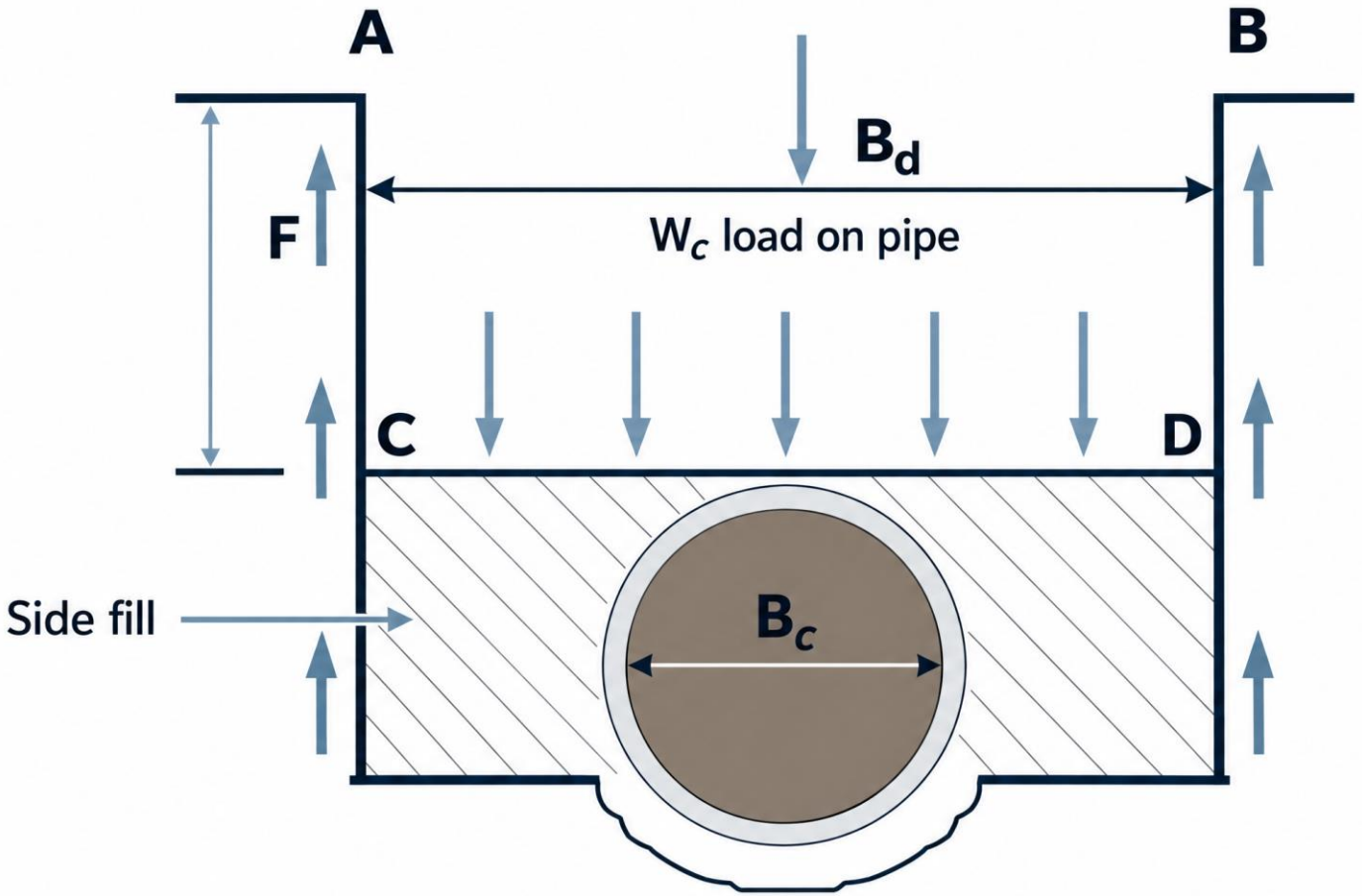
Vertical Pressures





Earth Load on Rigid Pipe

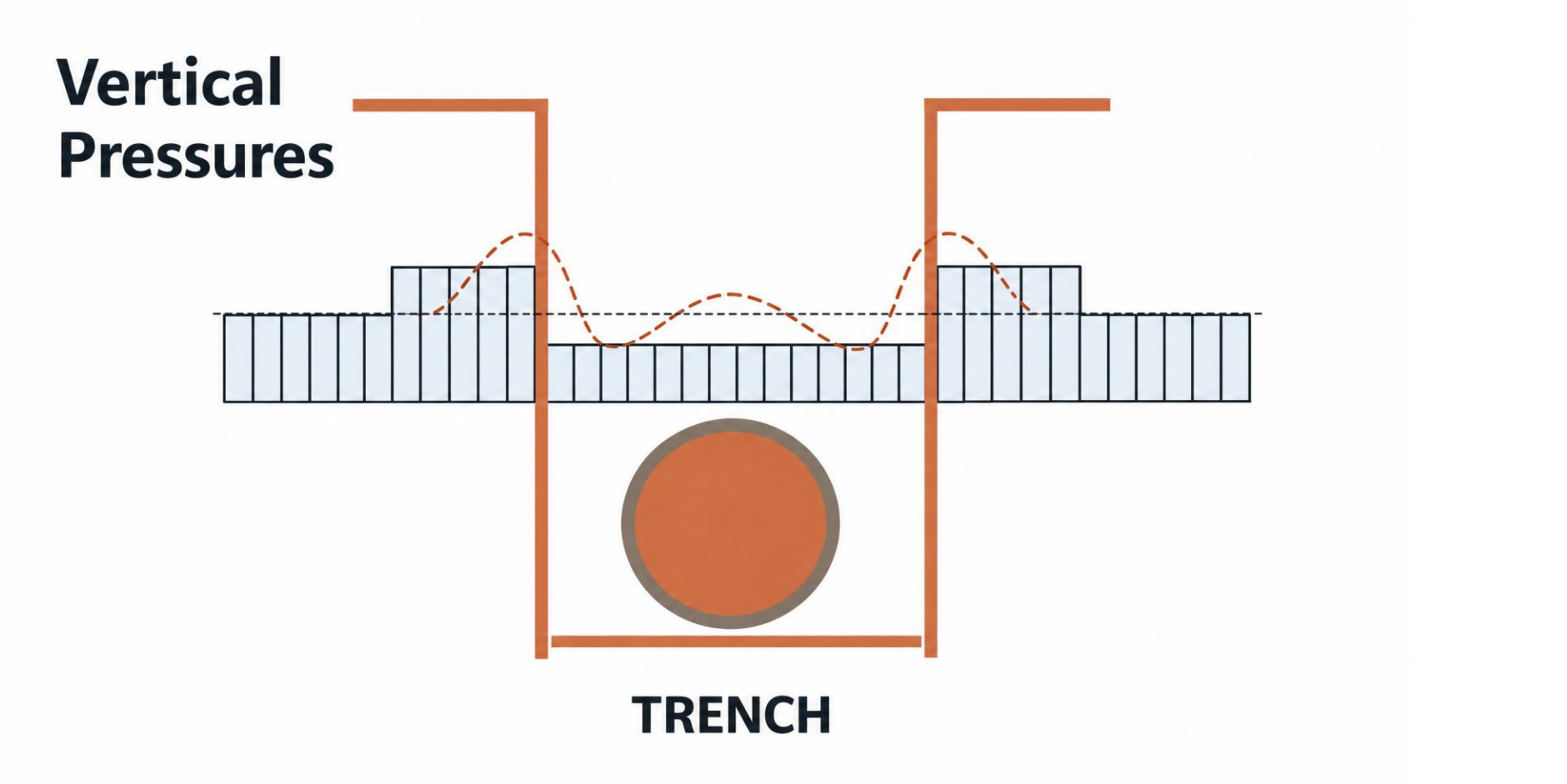
Trench Condition



P = weight of backfill, ABCD; F = upward shear on AC, BD

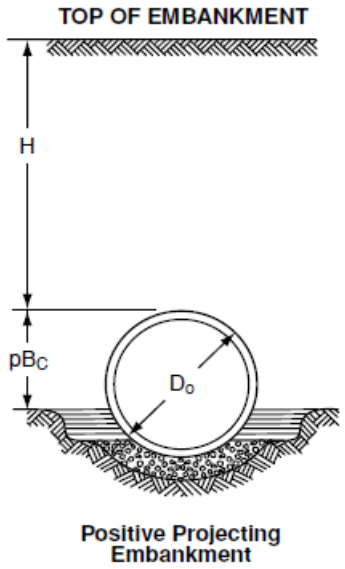
$W = P - 2F$

Trench Condition

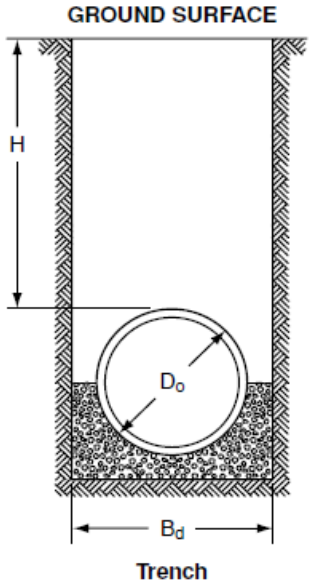


AASHTO LRFD 12.10.2.1

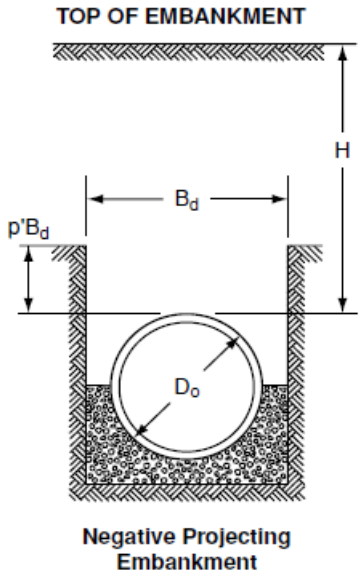
"Standard installations for both embankments and trenches shall be designed for positive projection, embankment loading conditions where F_e shall be taken as the vertical arching factor, VAF, specified in Table 12.10.2.1-3 for each type of standard installation."



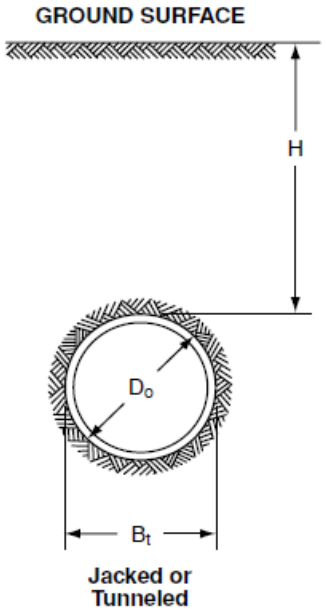
Positive Projecting Embankment



Trench

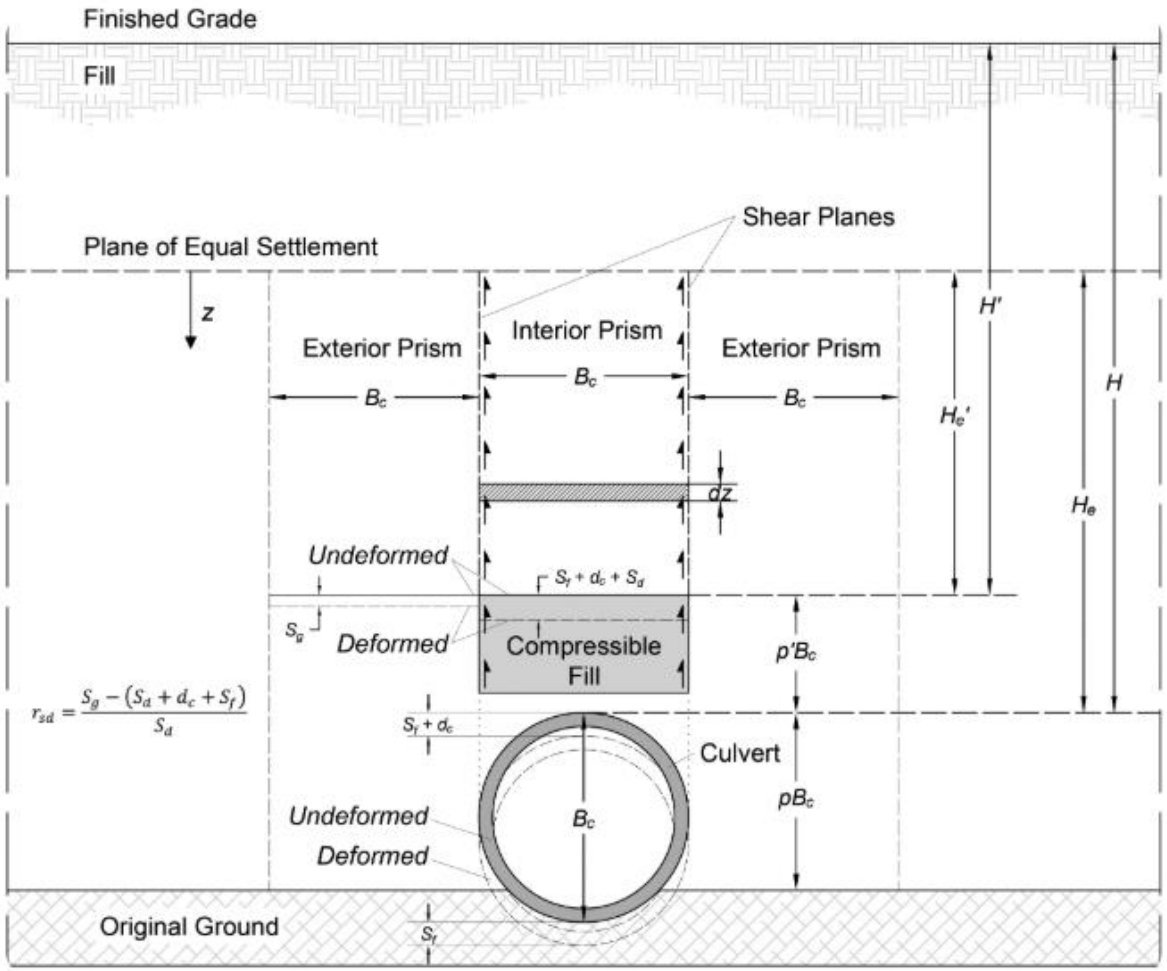


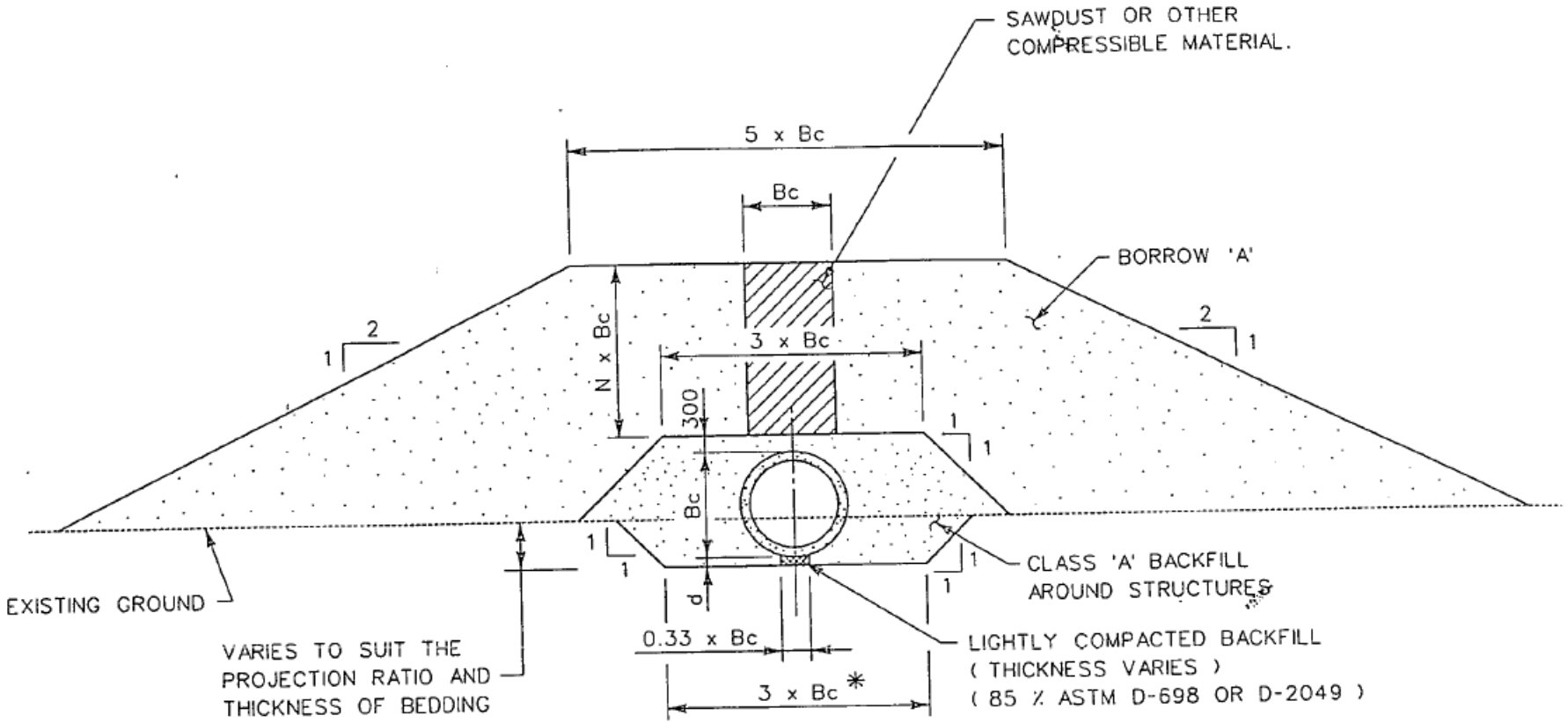
Negative Projecting Embankment



Jacked or Tunneled

Induced Trench





NOTE :
N IS GENERALLY BETWEEN 0.5 AND 2.0
Bc IS OUTSIDE DIAMETER OF PIPE
d IS THICKNESS OF BEDDING MATERIAL UNDER PIPE

* IF EXISTING SOIL CONDITIONS ARE OF A POOR NATURE THEN THIS DIMENSION SHOULD BE INCREASED TO 5 x Bc.

Mel C. Marshall Industrial Consultants Inc.

Technical & Marketing Services

December 20, 2001

Mr. J. Beakley
American Concrete Pipe Association
222 Las Colinas Blvd., Ste. 641
Irving, Texas
75039-5423

Dear Josh:

At our last TC meeting, I brought up the subject of induced trenching and told the committee of the success that New Brunswick is having with this technology. They have just completed the enclosed research project that confirms the success they have had. As a result, they continue to use induced trenches on a regular basis. As a matter of fact, Phil just e-mailed me some photos of a project they are presently working on.

Best wishes for a happy Christmas and a fabulous 2002!

Best regards,

Mel

Mel C. Marshall

ACPA

Induced Trenching

Contract #	Contract Name	Pipe Diameter	Pipe Class	Prism Depth	App. Fill Depth	Station
91 - 2554	Route #108	750	III	1.0 Bc	12.0400	3 + 632
91 - 6096	Route #1	1200	III	1.0 Bc	10.8150	8 + 350
95 - 2906	Route #2	1200	IV	1.0 Bc	14.4350	90 + 367
95 - 2913	Route #1	1370	IV	0.66 Bc	18.5400	71 + 365
95 - 2913	Route #1	1200	IV	1.0 Bc	11.3900	73 + 770
95 - 2915	Route #2	1200	IV	1.0 Bc	11.8400	13 + 460
95 - 2916	Route #2	1500	IV	1.0 Bc	12.3000	0 + 911
95 - 2916	Route #2	1200	IV	1.0 Bc	11.9950	2 + 501
95 - 2916	Route #2	1200	IV	1.0 Bc	9.5000	85 + 025
95 - 2916	Route #2	1500	IV	1.0 Bc	11.0400	97 + 394
95 - 2917	Route #2	1500	III	0.5 Bc	9.4850	128 + 080
95 - 2917	Route #2	1500	III	0.5 Bc	10.9000	528 + 110
95 - 2919	Route #2	1500	IV	1.0 Bc	10.2050	123 + 806
95 - 4321	Route #1	1800	V	0.9 Bc	22.8100	65 + 506
95 - 4331	Route #2	1800	III	0.5 Bc	9.9895	116 + 925
95 - 5060	Route #10	1800	IV	1.0 Bc	11.7500	3 + 070
95 - 8047	Route #2	(2) 1800	V	1.0 Bc	13.4615	218 + 523
96 - 2930	Route #2	1500	IV	0.5 Bc	13.6150	60 + 500
96 - 2930	Route #2	1500	IV	0.5 Bc	12.3050	4 + 470
96 - 2930	Route #2	1500	IV	1.5 Bc	21.1600	6 + 957
97 - 2935	Route #1	750	IV	0.5 Bc	11.8900	56 + 992
97 - 2935	Route #1	750	III	0.5 Bc	8.9400	78 + 000
97 - 2935	Route #1	1050	IV	0.5 Bc	10.4400	78 + 825
97 - 2935	Route #1	1050	III	0.5 Bc	11.8400	59 + 050
97 - 2935	Route #1	2400	IV	1.0 Bc	16.5800	57 + 750
97 - 2935	Route #1	2400	V	0.75 Bc (2)	32.3700	60 + 300
97 - 2936	Route #1	1200	V	1.5 Bc	32.4975	82 + 350
97 - 2936	Route #1	2100	IV	0.5 Bc	15.3900	64 + 066
97 - 2936	Route #1	2100	IV	0.5 Bc	12.5700	84 + 113
97 - 2941	Route #2	1800	III	1.0 Bc	11.8250	44 + 513
97 - 2941	Route #2	1200	III	1.0 Bc	9.0150	103 + 663
97 - 2941	Route #2	1050	III	1.0 Bc	10.1350	104 + 105
97 - 2941	Route#2	1200	III	1.0 Bc	10.2050	3 + 626

ACPA

4.0 Conclusion

As previously mentioned, there was no structural damage observed that would have resulted from failure of the induced trenches. All of these induced trenches were installed at least two years ago, and the post installation settling would have already occurred. Therefore, if no damage was observed at this time, most likely no serious damage should be expected in the future.

Although there may be some doubt within the pre-cast design community as to whether the induced trenching technique is truly a reliable construction practice, our study shows evidence that indicates successful applications in New Brunswick.

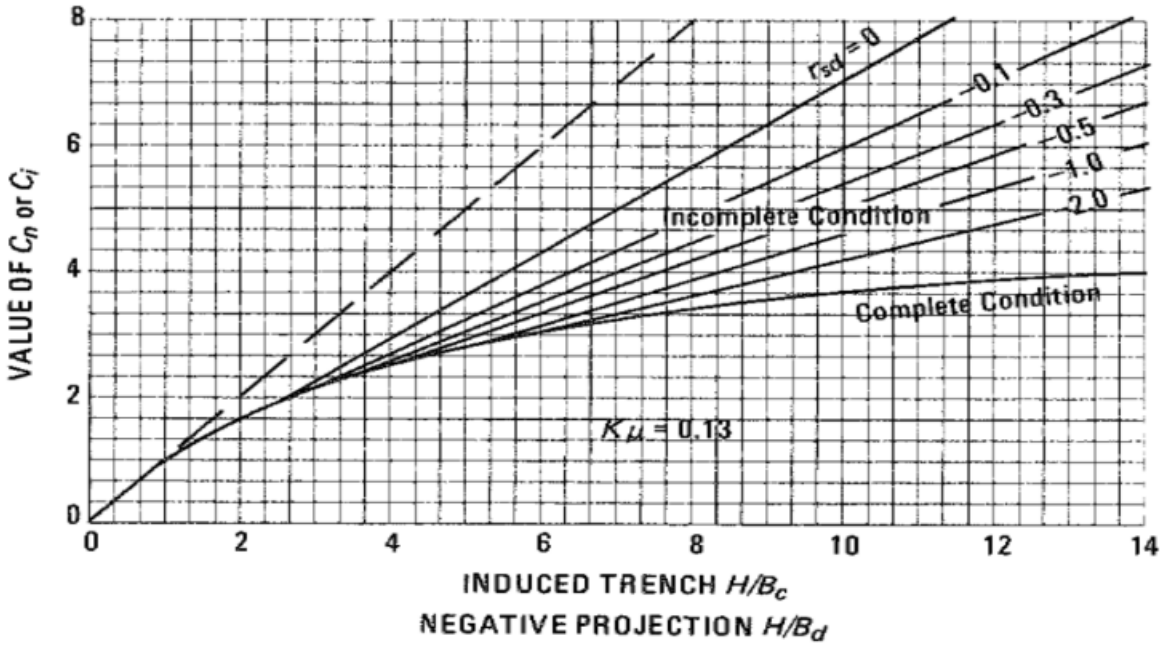
Spangler's Equation for Induced Trench

$$\frac{e^{-2K\mu\frac{H'_e}{B_d}}-1}{-2K\mu}\left[\frac{H'}{B_d}-\frac{H'_e}{B_d}-\frac{1}{2K\mu}\right]-\frac{H'_e}{B_d}\left[\left(\frac{H'}{B_d}-\frac{H'_e}{B_d}\right)+\frac{1}{2}\frac{H'_e}{B_d}-\frac{1}{2K\mu}\right]$$
$$=\frac{2}{3}r_{sd}p'\left[\frac{e^{-2K\mu\frac{H'_e}{B_d}}-1}{-2K\mu}+\left(\frac{H'}{B_d}-\frac{H'_e}{B_d}\right)e^{-2K\mu\frac{H'_e}{B_d}}\right] \quad (4.31)$$

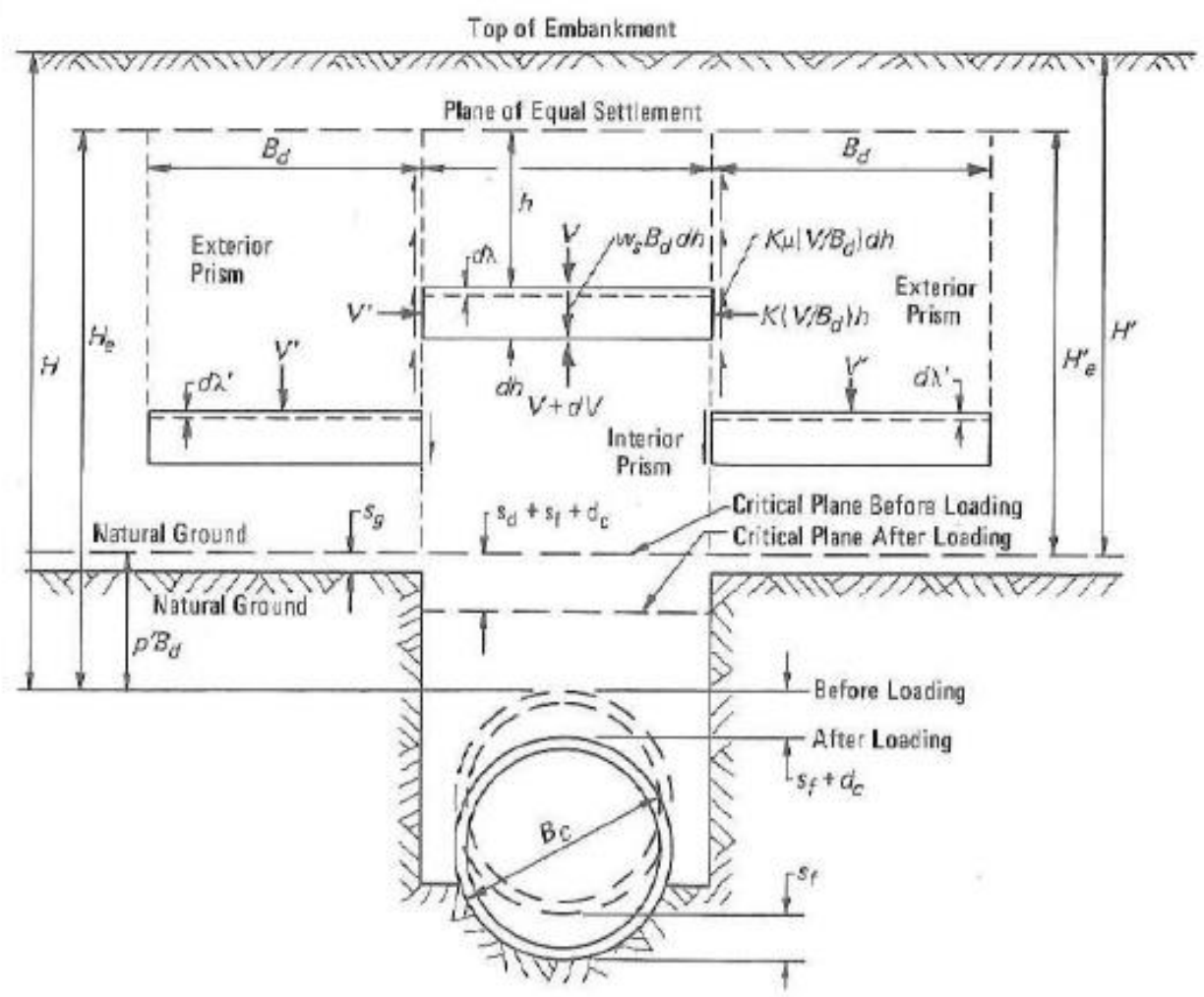
Table 4.2 *Design Values of Settlement Ratio*

Installation and Foundation Condition	Settlement Ratio r_{sd}	
	Usual Range	Design Value
Positive Projection	0.0 to +1.0	
Rock or Unyielding Soil	+1.0	+1.0
*Ordinary Soil	+0.5 to +0.8	+0.7
Yielding Soil	0.0 to +0.5	+0.3
Zero Projection		0.0
Negative Projection	-1.0 to 0.0	
$p' = 0.5$		-0.1
$p' = 1.0$		-0.3
$p' = 1.5$		-0.5
$p' = 2.0$		-1.0
Induced Trench	-2.0 to 0.0	
$p' = 0.5$		-0.5
$p' = 1.0$		-0.7
$p' = 1.5$		-1.0
$p' = 2.0$		-2.0

**The value of the settlement ratio depends on the degree of compaction of the fill material adjacent to the sides of the pipe. With construction methods resulting in proper compaction of bedding and sidefill materials, a settlement ratio design value of +0.5 is recommended.*



Settlement Ratio



$$r_{sd} = \frac{s_g - (s_d + s_f + d_c)}{s_d}$$

S_g = ground settlement
S_d = fill settlement
S_f = foundation settlement
d_c = deflection of pipe

LightWeight Materials

Material	Unit Weight (pcf)	Elastic Modulus (psi)
Geofoam	1.2 to 2	50 to 100
Foamed Glass	12 to 15	145,000
Sawdust	20 to 30	50
Shredded Tires	30 to 35	140 to 150
Lightweight Cellular Concrete	40 to 50	160,000
Lightweight Aggregate	50 to 60	6000
Uniform Gravel	100 to 120	5,800
Hay	N/A	N/A

“Bedding and Fill Heights for Concrete Roadway Pipe and Box Culverts”

C.H. Yoo, F. Parker, J. Kang, Auburn University, 2005

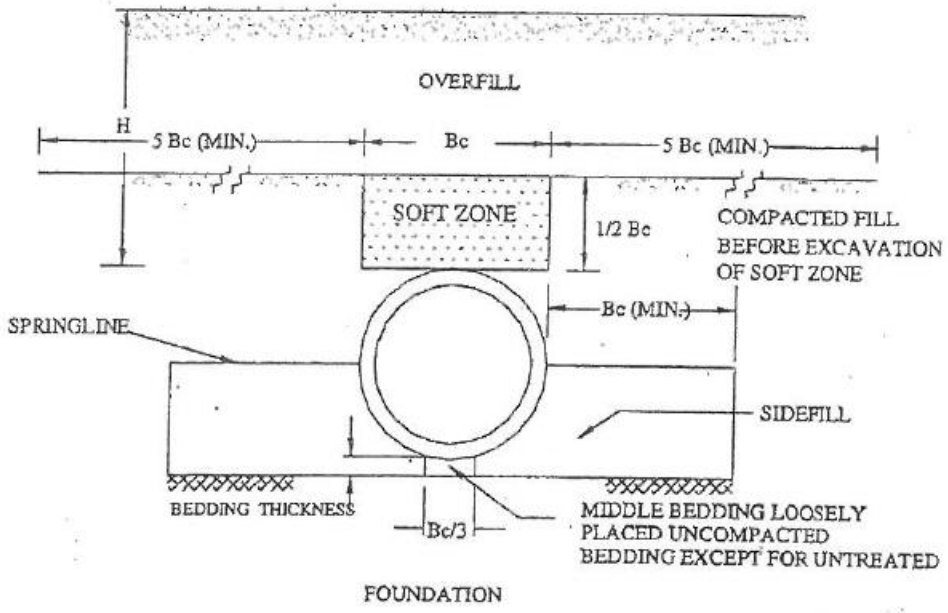


Figure 4.12 Geometry I of Soft Zone for Concrete Round Pipes

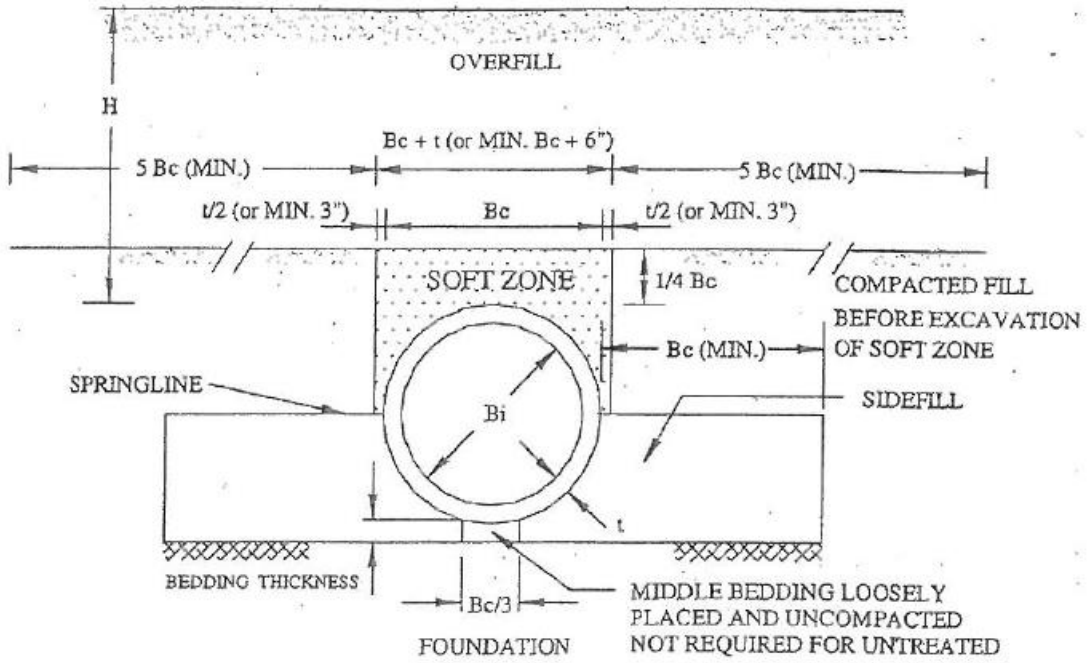


Figure 4.13 Geometry II of Soft Zone for Concrete Round Pipes

Reduction Factors

"Bedding and Fill Heights for Concrete Roadway Pipe and Box Culverts"

C.H. Yoo, F. Parker, J. Kang, Auburn University, 2005

Table 6.8 Proposed Equations for the Reduction Rate of Soft Materials – Concrete Pipe

Soft Zone	Foundation	Sidefill Compaction	Equations for Reduction Rate
Geometry I	Yielding Or Unyielding	TREATED	$R = 0.445 - 6\times10^{-4} E_s$
		UNTREATED	$R = 0.345 - 4\times10^{-4} E_s$
Geometry II	Yielding Or Unyielding	TREATED	$R = 0.824\, e^{-0.0027 E_s}$
		UNTREATED	$R = 0.821 e^{-0.0037 E_s}$

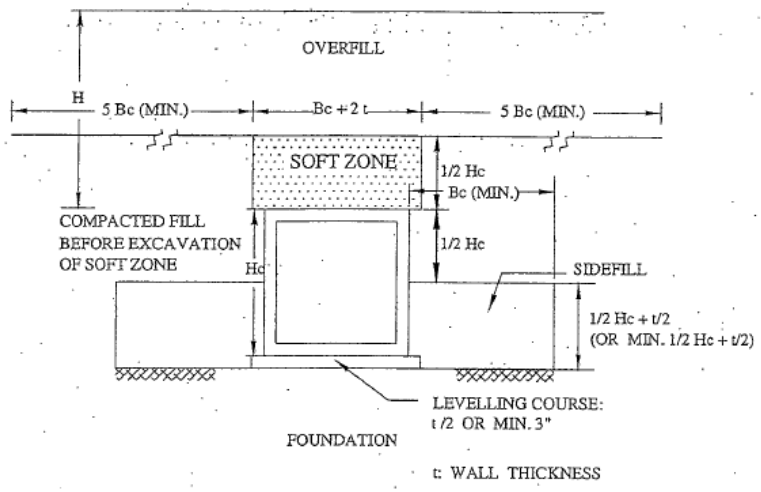


Figure 4.33 Geometry I of Soft Zone for Box Culverts

Table 4.7 Proposed Equations for the Reduction Rate of Soft Materials – Box Culverts

Soft Zone	Foundation	Sidefill Compaction	Equations for Reduction Rate
Geometry I	Yielding	TREATED	$R = -0.0003\ E_s + 0.275$
		UNTREATED	$R = -0.0004\ E_s + 0.355$
	Unyielding	TREATED	$R = -0.0004\ E_s + 0.374$
		UNTREATED	$R = -0.0005\ E_s + 0.407$

ACPA

Comparison

Auburn Method:

$ID := 48$ pipe inside diameter (in)

$t := 5$ pipe wall thickness (in)

$Bc := \frac{ID + 2 \cdot t}{12}$ $Bc = 4.833$ pipe outside diameter (ft)

$\gamma s := 120$ unit weight of soil (pcf)

$H := 50$ height of cover (ft)

$Es := 100$ modulus of geofoam (psi)

$R := 0.445 - 6 \cdot 10^{-4} \cdot Es$ $R = 0.385$ Auburn equation for reduction factor "Treated" soil.

$VAFi := 1 - R$ $VAFi = 0.615$ Vertical Arching Factor from the Induced Trench

Soil Prism Load:

$PL := \gamma s \cdot \left(H + \frac{Bc \cdot (4 - \pi)}{8} \right) \cdot Bc$ $PL = 2.93 \cdot 10^4$ soil prism load (lbs/ft)

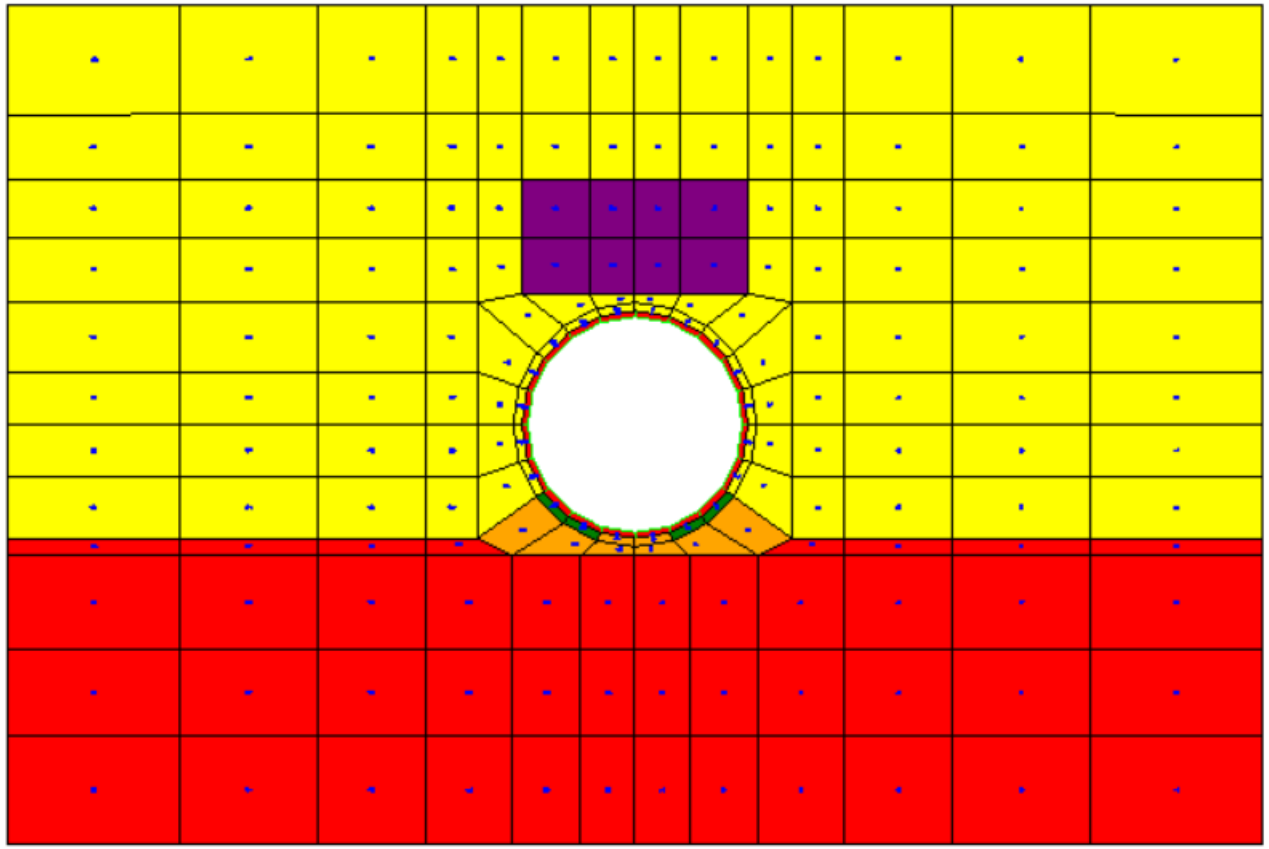
$VAFe := 1.40$ Vertical Arching Factor or a Type 2 Positive Projecting Embankment Installation

$We := VAFi \cdot VAFe \cdot PL$ $We = 2.523 \cdot 10^4$

Spangler Method p = 0.5, Ku = 0.13	Soil Load (lbs/ft)	VAF
r_{sd} = -0.1	22,990	0.784
r_{sd} = -0.2	21,940	0.749
r_{sd} = -0.3	21,250	0.725
r_{sd} = -0.4	20,690	0.706
r_{sd} = -0.5	20,160	0.688

0.615 x 1.4 = 0.861

EPS (100 psi) Per JB



Hs/Bc	VAF
0.5	0.80
1.0	0.69
1.5	0.60
2.0	0.53
2.5	0.47

0.615*1.4 = 0.861

Comparison

H_s/Bc	JB VAF	Spangler VAF
0.5	0.8	0.69
1.0	0.69	0.58
1.5	0.60	0.50
2.0	0.53	0.46
2.5	0.47	0.42

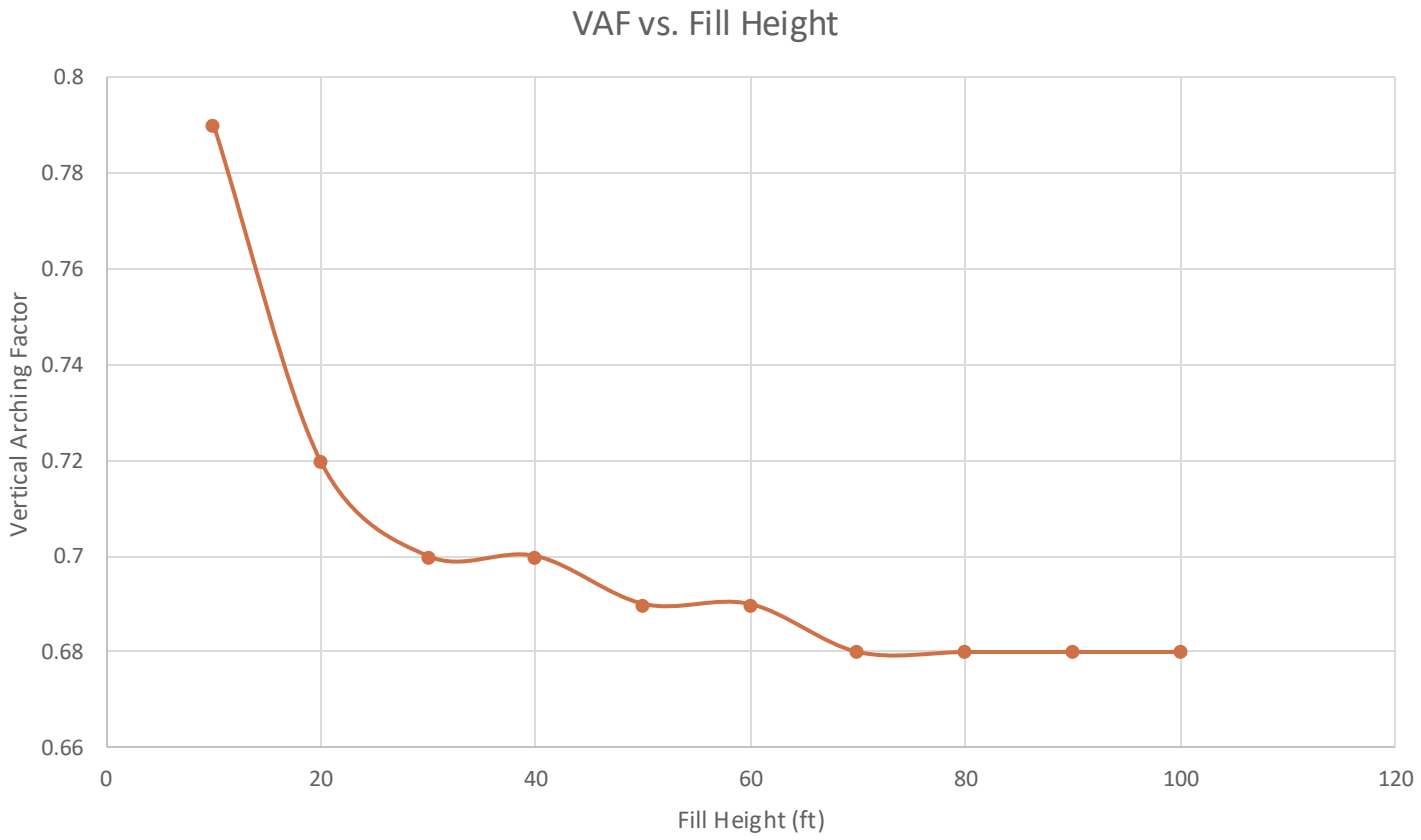
Values used with Spangler Method

r_{sd} = -0.5

Ku = 0.130

H = 50 ft

Change in VAF with Fill Height



$H_s = 0.5 * B_c$

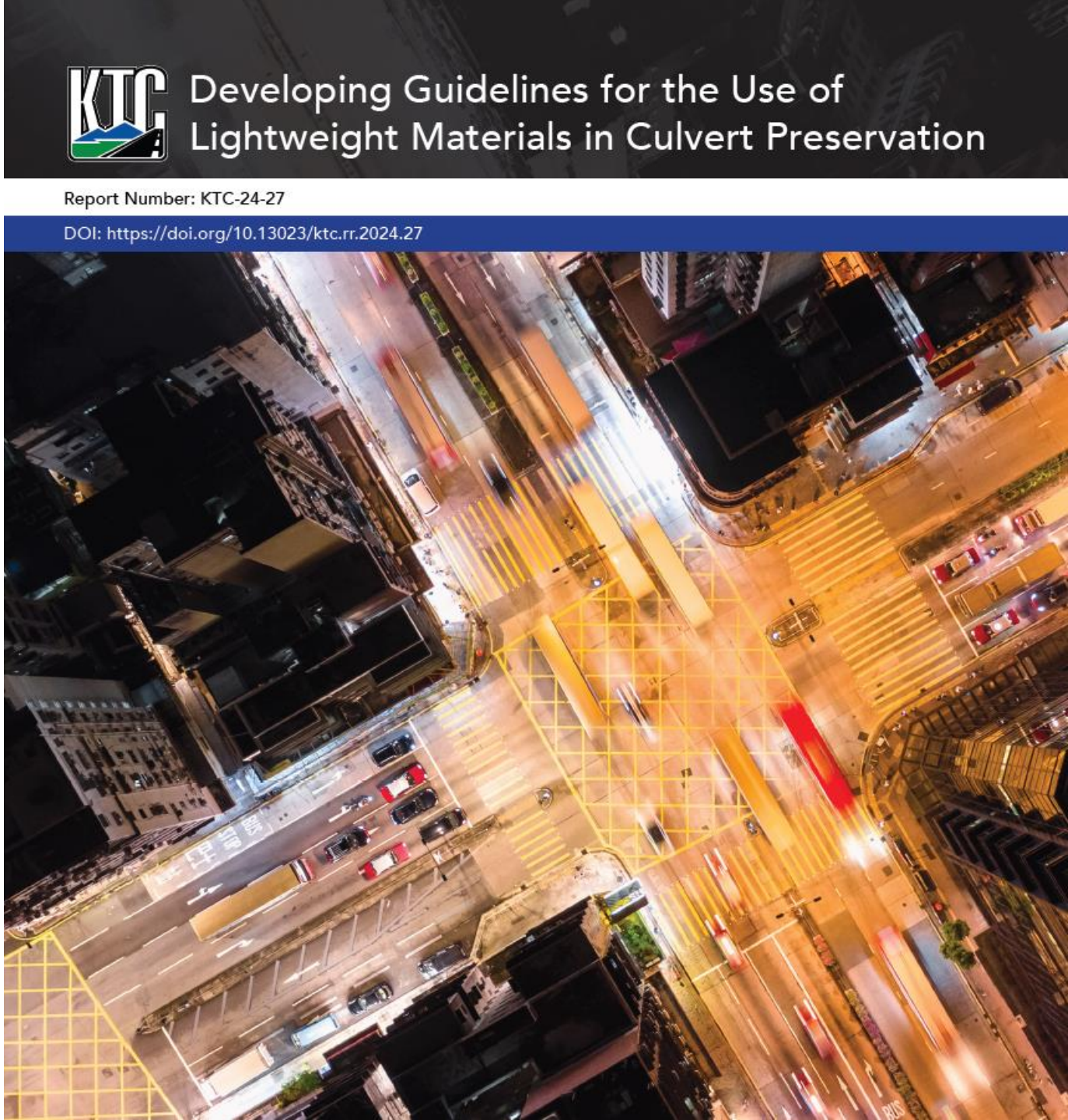
$r_{sd} = -0.5$

Ku = 0.130

ID = 48

Another Option

$$Ratio = a_{00} + \left[a_{10} + a_{11}\left(\frac{t}{W}\right) + a_{12}\left(\frac{t}{W}\right)^2 + a_{13}\left(\frac{t}{W}\right)^3\right] * \left[a_{20} + a_{21}\left(\frac{L}{W}\right) + a_{22}\left(\frac{L}{W}\right)^2 + a_{23}\left(\frac{L}{W}\right)^3\right] * \left[a_{30} + a_{31}\left(\frac{E_{LW}}{E_0}\right) + a_{32}\left(\frac{E_{LW}}{E_0}\right)^2 + a_{33}\left(\frac{E_{LW}}{E_0}\right)^3\right] * \left[a_{40} + a_{41}\left(\frac{\gamma_{LW}}{\gamma_0}\right) + a_{42}\left(\frac{\gamma_{LW}}{\gamma_0}\right)^2 + a_{43}\left(\frac{\gamma_{LW}}{\gamma_0}\right)^3\right] * \left[a_{50} + a_{51}\left(\frac{E_{soil}}{E_0}\right) + a_{52}\left(\frac{E_{soil}}{E_0}\right)^2 + a_{53}\left(\frac{E_{soil}}{E_0}\right)^3\right] * \left[a_{60} + a_{61}\left(\frac{\gamma_{soil}}{\gamma_0}\right) + a_{62}\left(\frac{\gamma_{soil}}{\gamma_0}\right)^2 + a_{63}\left(\frac{\gamma_{soil}}{\gamma_0}\right)^3\right] * \left[a_{70} + a_{71}\left(\frac{d}{W}\right) + a_{72}\left(\frac{d}{W}\right)^2 + a_{73}\left(\frac{d}{W}\right)^3\right] * \left[a_{80} + a_{81}\left(\frac{h}{W}\right) + a_{82}\left(\frac{h}{W}\right)^2 + a_{83}\left(\frac{h}{W}\right)^3\right]$$



Compare the 3 Options

Method	Load (lbs/ft)	VAF
Spangler	43,560	0.726
Auburn	46,940	0.766*
KTC	40,200	0.670*

<u>10 foot wide box</u>

H = 50 ft.

E_{geo} = 100 psi

E_{soil} = 2000 psi

r_{sd} = -0.5

Ku = 0.13

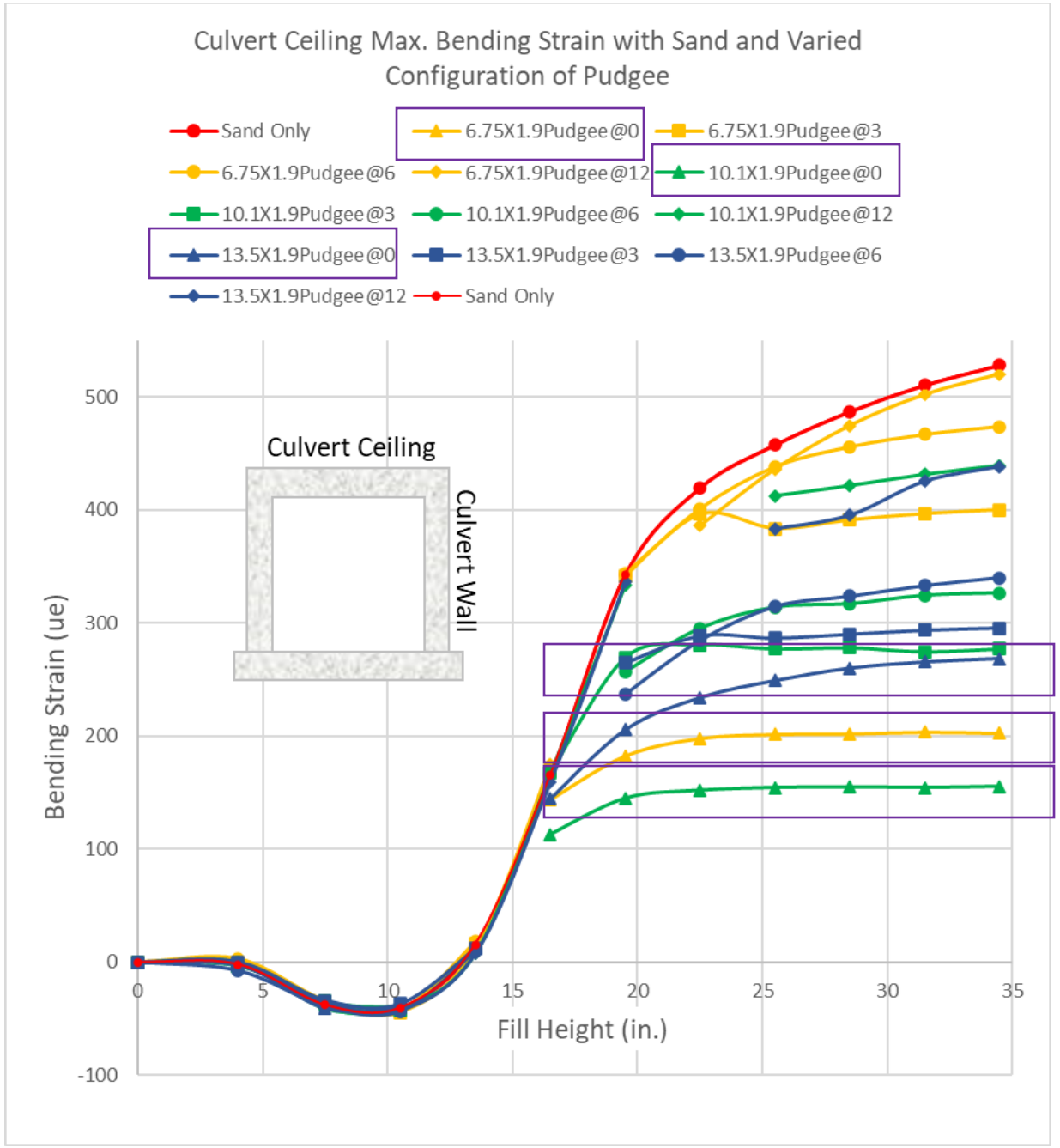
P = 0.5

*VAF = Load Ratio * 1.15 for box culvert

Width Effect

From KTC Report





Design Loading on Deeply Buried Box Culverts

K. Kim & C.H. Yoo, Journal of Geotechnical and Geoenvironmental Engineering, ASCE/January 2005

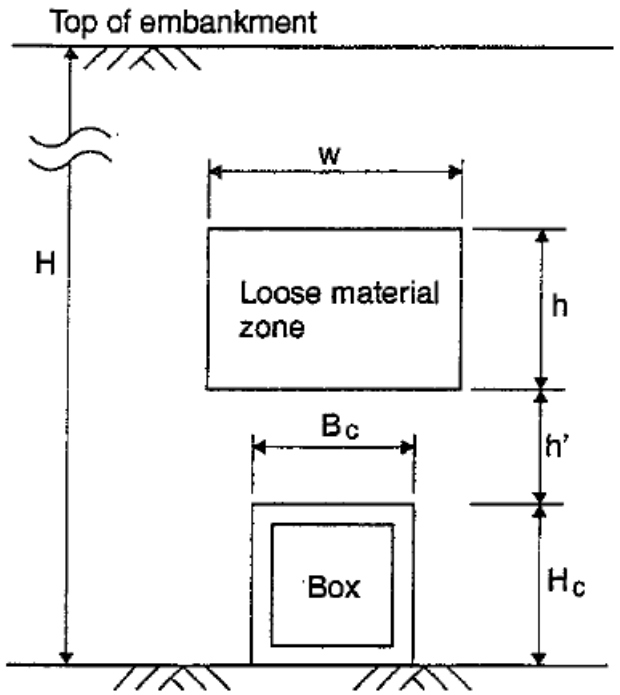


Fig. 11. Concept and notation in imperfect trench installations

H = 100 ft.

h = H_c = 8 ft.

B_c = 8 ft.

Table 2. Load Reduction Rates (%) Due to Imperfect Trench Installation

Modulus of lightweight material	Width of back fill layer, w/B_c			
	1.0	1.5	2.0	2.5
47.9 kPa (100 ksf)	32.8	41.1	39.1	36.7
23.9 kPa (50 ksf)	43.6	58.6	57.0	54.3
4.79 kPa (10 ksf)	56.9	83.7	85.3	84.8

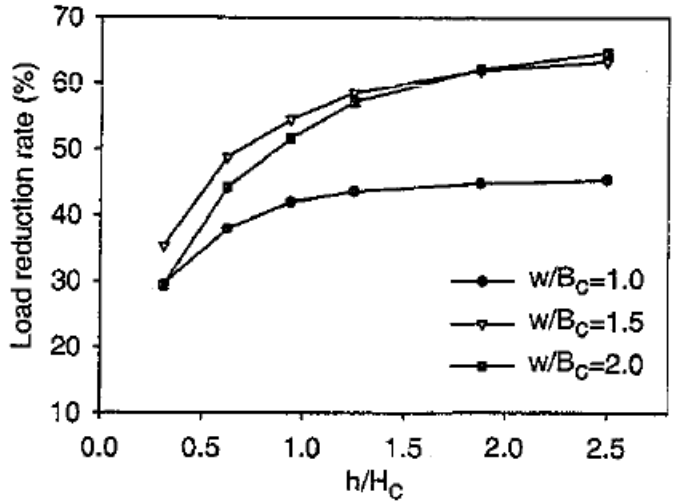


Fig. 12. Effects of w/B_c and h/H_c in imperfect trench installations

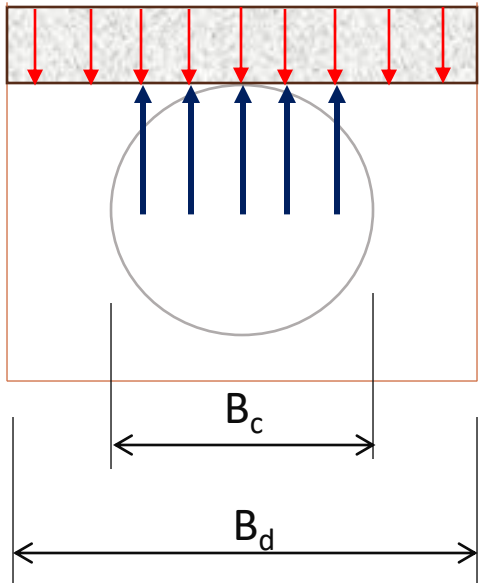
Spangler Width Effect

Bd (Width of Soft Material) (ft)	Soil Load - Rigid Pipe (lbs/ft)	Soil Load - Flexible Pipe (lbs/ft)
10 ft.	43,560	43,560
11 ft.	48,780	44,460
12 ft.	54,020	45,230
13 ft.	59,350	45,950
14 ft.	64,710	46,590
15 ft.	70,090	47,160

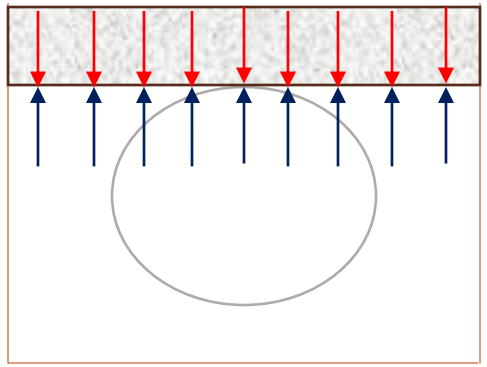
<u>10 foot wide culvert</u>
H = 50 ft.
r_{sd} = -0.5
Ku = 0.13
p = 0.5 (for 10 foot width – changes with depth)

Embankment Load with F_e = 1.15 is 70,480 lbs/ft

Spangler's Rigid vs. Flexible



Rigid Pipe



Flexible Pipe

Resulting Lateral Pressure

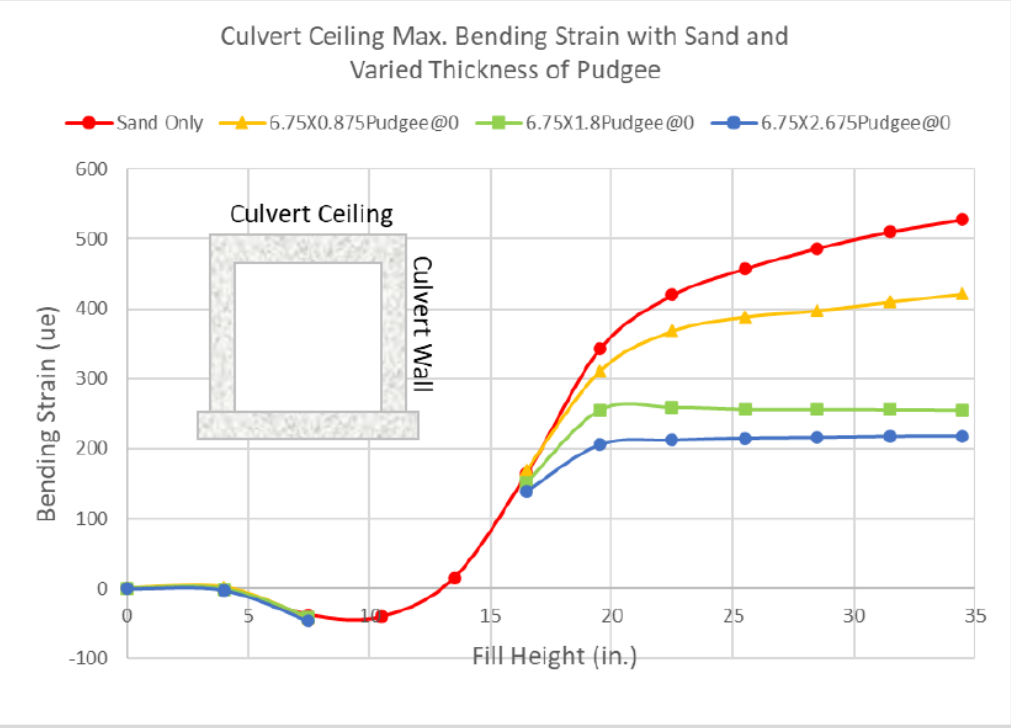


Figure 3.6 Culvert Ceiling Maximum Bending Strains — Sand Only and Pudgee Inclusions

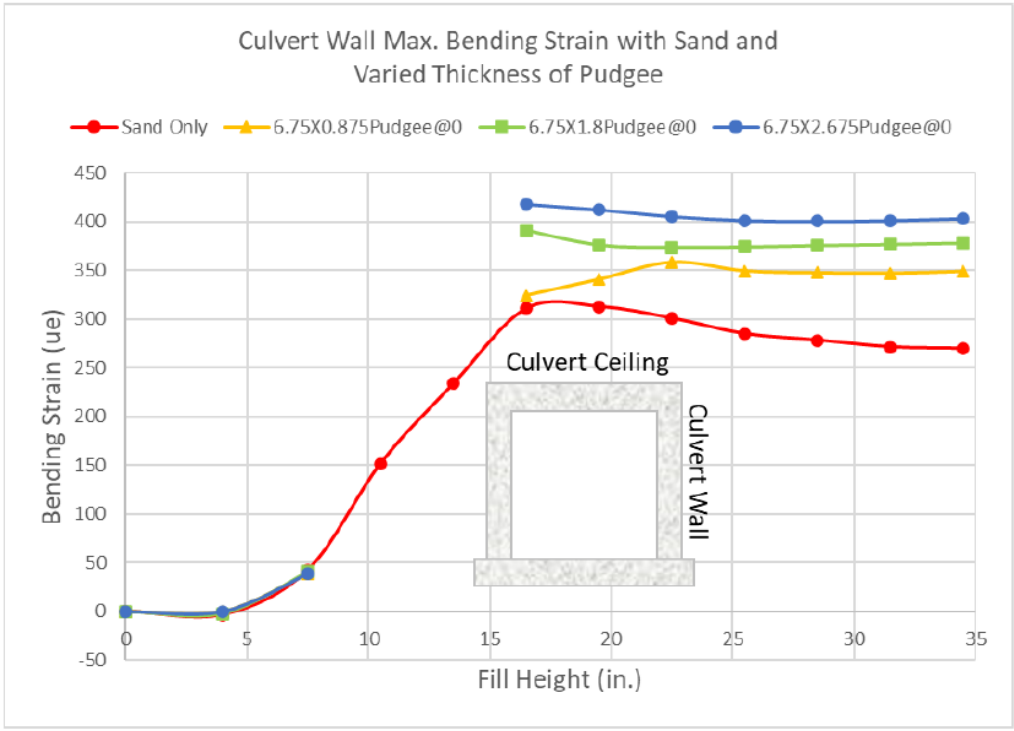


Figure 3.7 Culvert Wall Maximum Bending Strains — Sand Only and Pudgee Inclusions

220/550 = 0.4

410/275 = 1.5

From KTC Report

Resulting Lateral Pressure

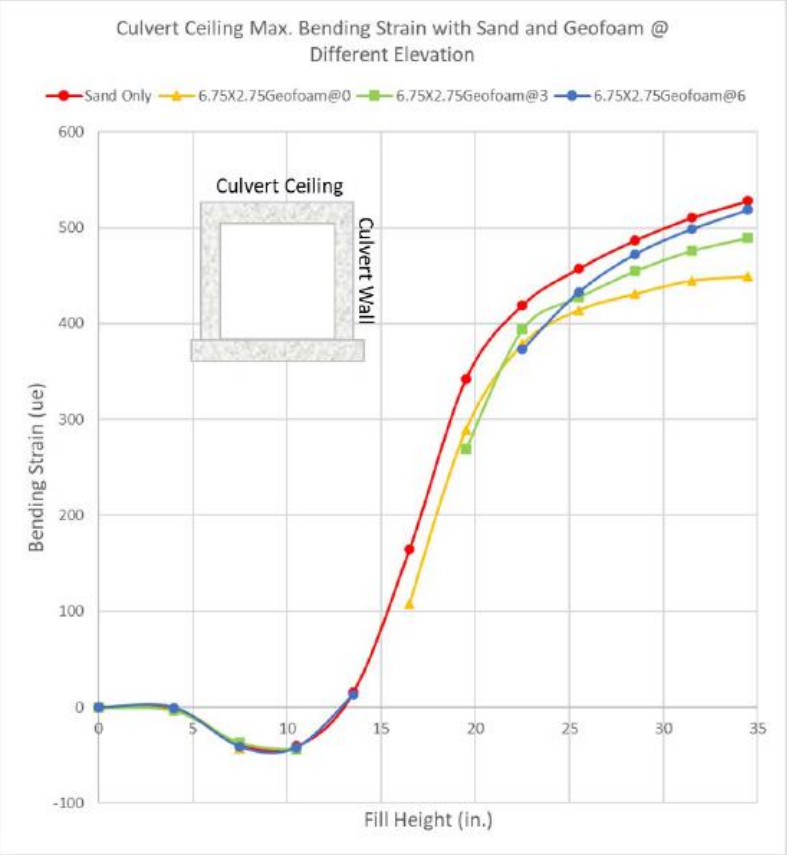


Figure 3.10 Culvert Ceiling Maximum Bending Strains — Sand Only and Geofoam Inclusions

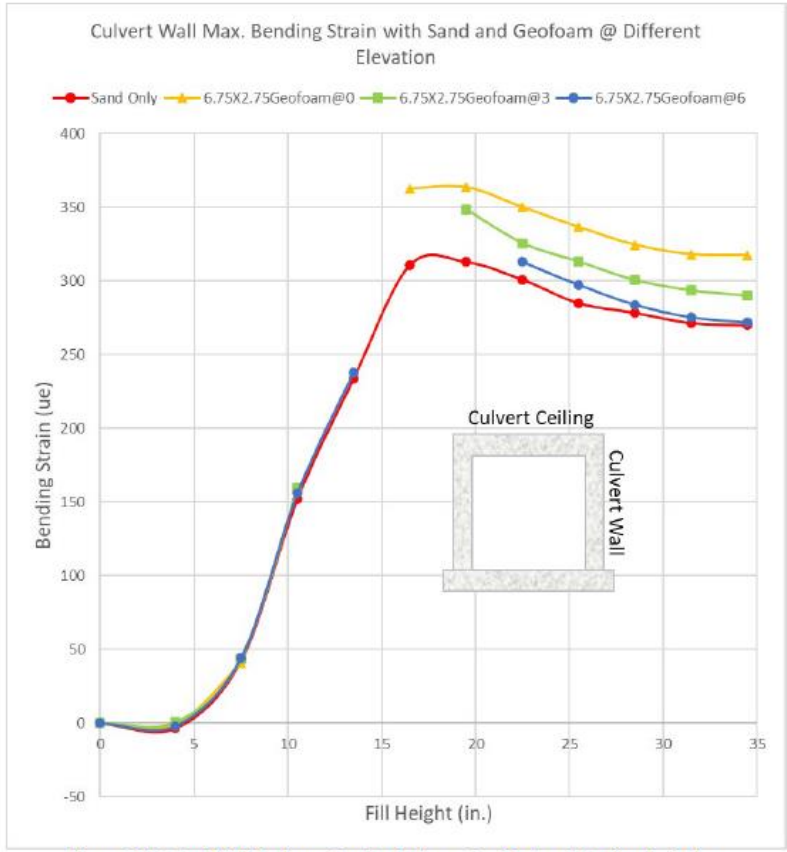


Figure 3.11 Culvert Wall Maximum Bending Strains — Sand Only and Geofoam Inclusions

440/530 = 0.83

320/270 = 1.19

From KTC Report

“Load Reduction (Arching) on Buried Rigid Culverts Using Geofoam: Long-Term Behaviour”

EuroGeo4 Paper Number 318, J. Vaslestad, B. Bartlomiej, & T.H. Johansen, 2008

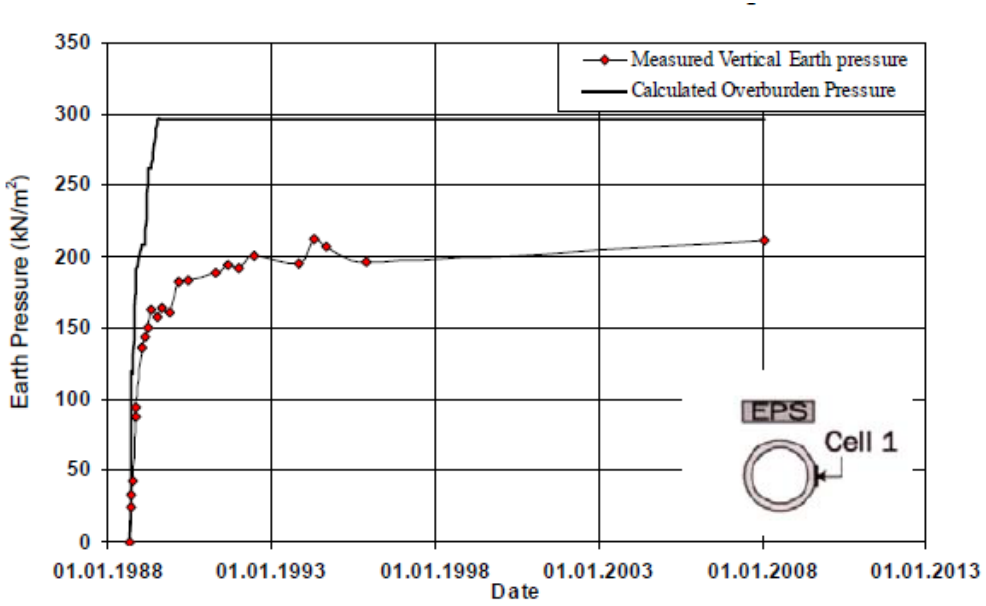


Figure 3. Measured earth pressures in cell 1 at Eidanger

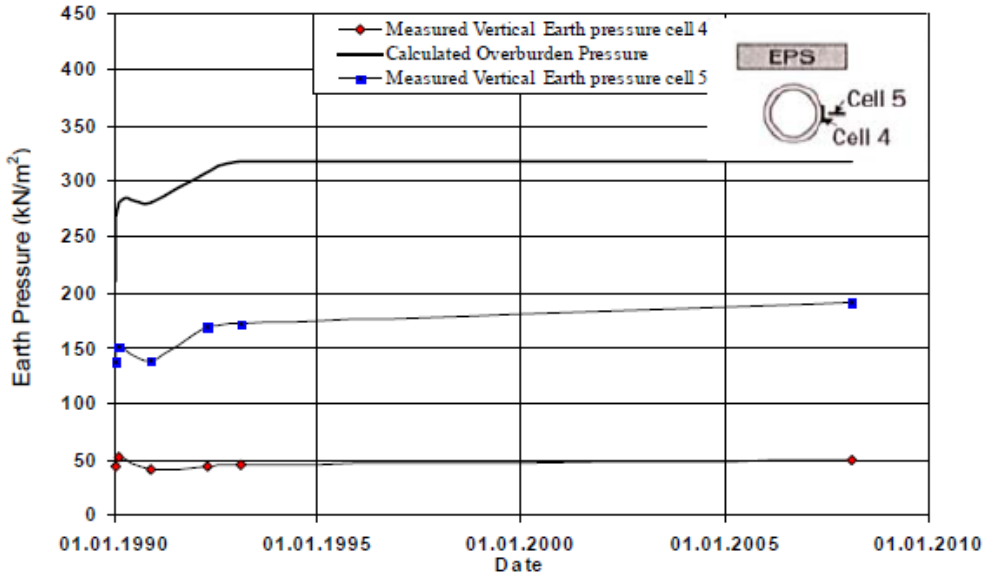


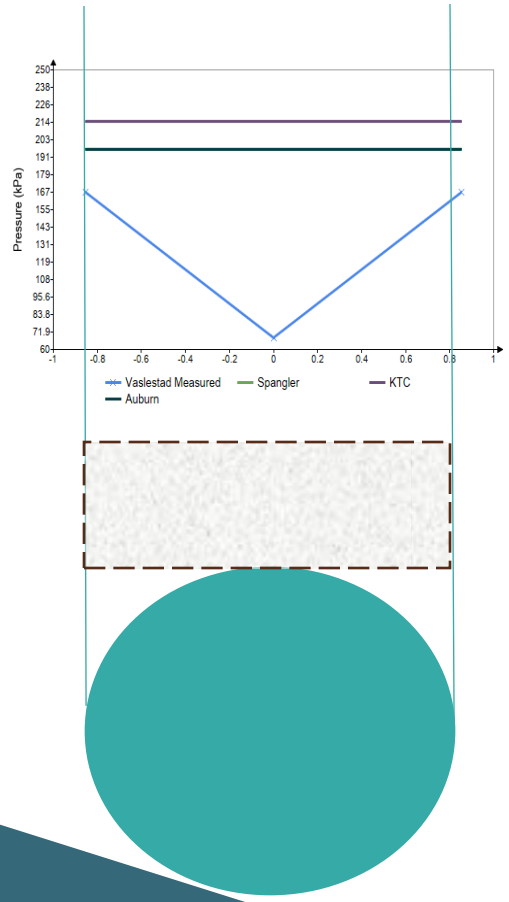
Figure 9. Measured earth pressures in cells 4 and 5 at Sveio

W_{EPS} = 1*O.D.
H = 15 m
H_{ft} = 0.5 m
H_s = 0.5 m
h.e.p. = 72% of Overburden

W_{EPS} = 1.5*O.D.
H = 15 m
H_{ft} = 0.2 m
H_s = 0.5 m
h.e.p. = 17% of Overburden

“Load Reduction (Arching) on Buried Rigid Culverts Using Geofoam: Long-Term Behaviour”

EuroGeo4 Paper Number 318, J. Vaslestad, B. Bartlomiej, & T.H. Johansen, 2008

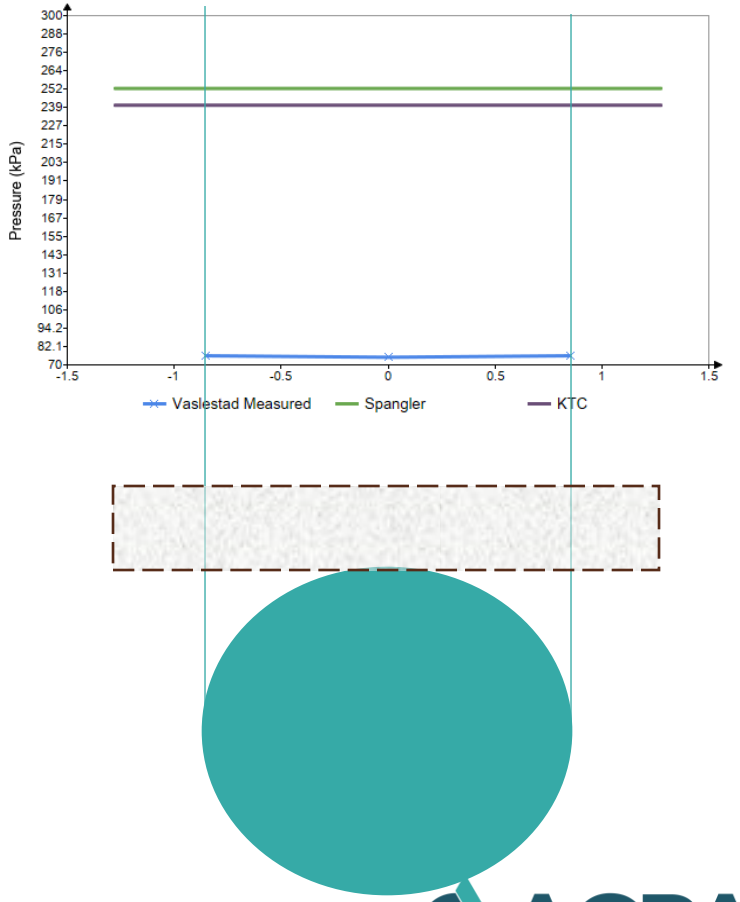


Conclusion:

“…Based on the full scale tests and finite element analyses, it is recommended to use expanded polystyrene of width at least 1.5 times the outer diameter of the pipe……”

B_c = 1.71 m
$B_d = B_c$
H_s = 0.5 m
H = 14 m

B_c = 1.71 m
$B_d = B_c$ x 1.5
H_s = 0.2 m
H = 15 m



For Spangler:
γ_s = 20 kN/m^3
Ku = 0.192 – granular material
r_{sd} = -0.5

Used flexible pipe design method

The Importance of Stiffness/Modulus

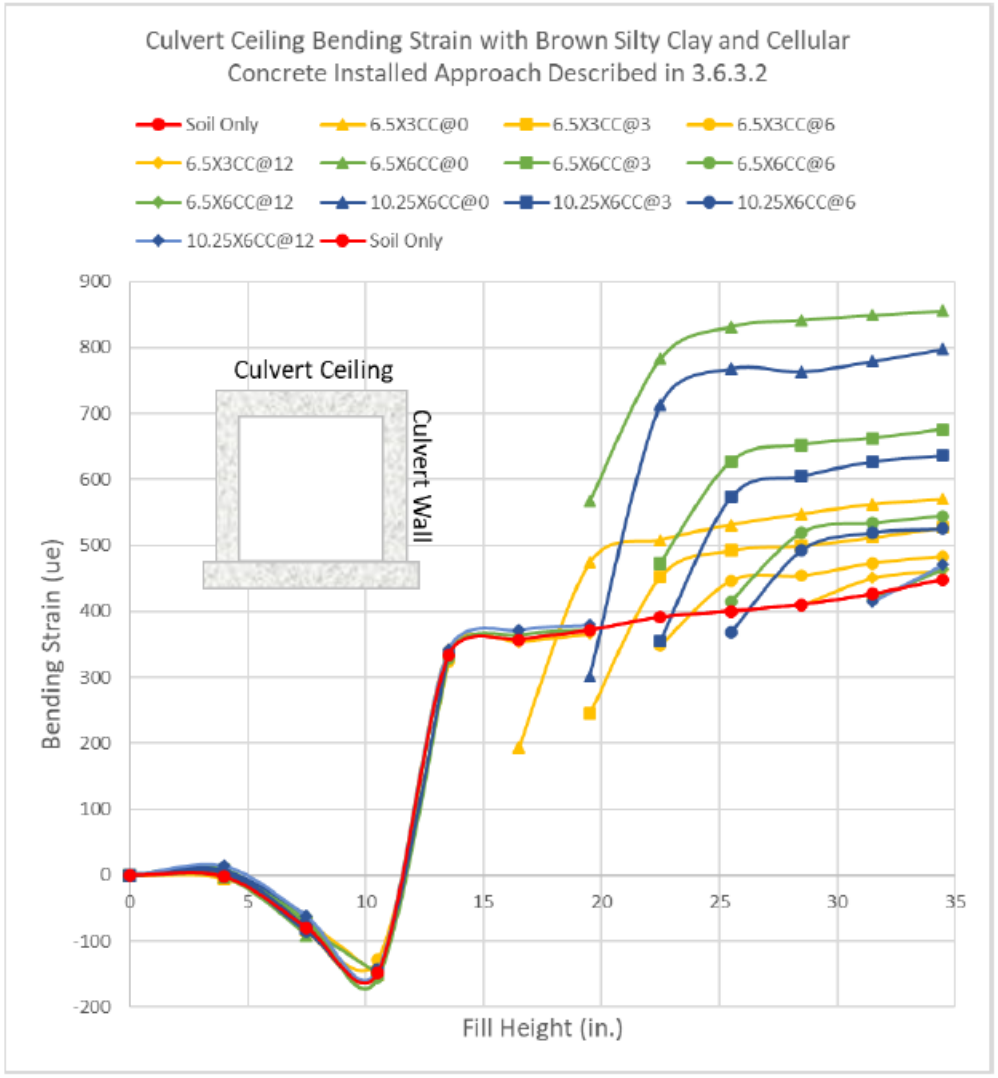


Figure 3.18 Culvert Ceiling Maximum Bending Strains — Soil Only and Cellular Concrete Block

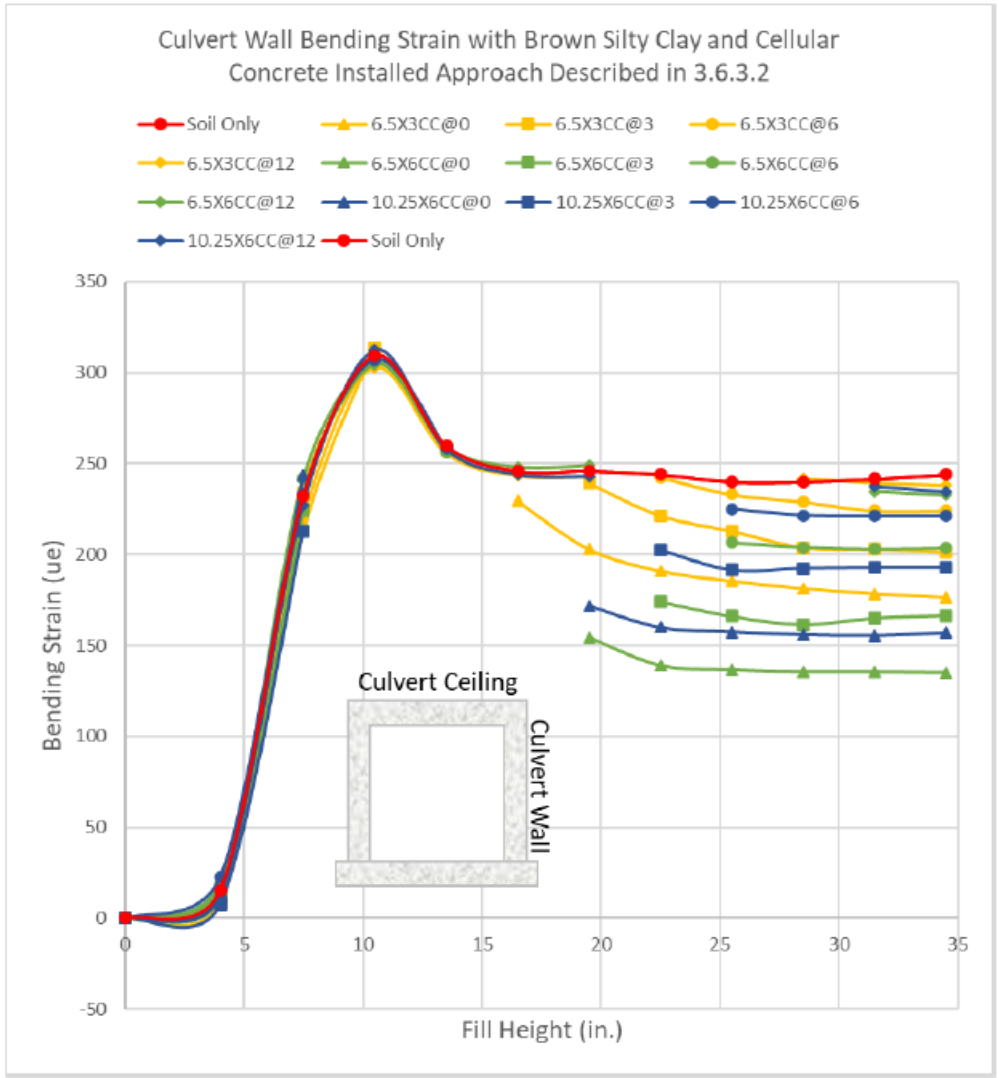


Figure 3.19 Culvert Wall Maximum Bending Strains — Soil Only and Cellular Concrete Block

Silty Clay - γ_s = 108 pcf, E_s = 418 ksf Cellular Concrete - γ_c = 45 pcf, E_c = 22,600 ksf

ACPA

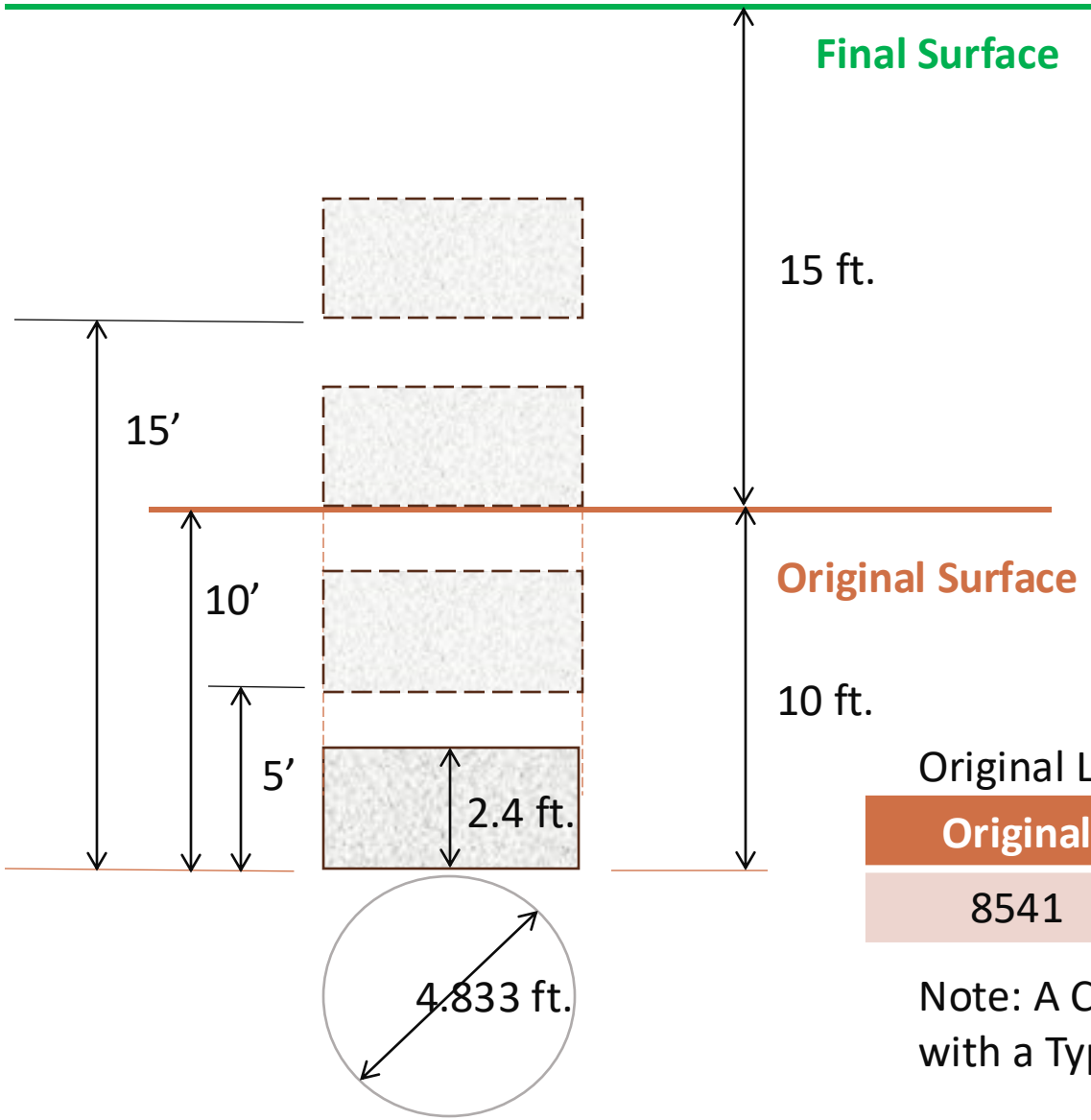
LightWeight Materials

Material	Unit Weight (pcf)	Elastic Modulus (psi)
Geofoam	1.2 to 2	50 to 100
Foamed Glass	12 to 15	145,000
Sawdust	20 to 30	50
Shredded Tires	30 to 35	140 to 150
Lightweight Cellular Concrete	40 to 50	160,000
Lightweight Aggregate	50 to 60	6000
Uniform Gravel	100 to 120	5,800
Hay	N/A	N/A



ACPA

Effect of Location of Soft Zone Above Culvert



Height from Top of Culvert (H_T)	KTC VAF	Spangler VAF
0	0.66 x 1.4 = 0.924	0.71
5	0.72 x 1.4 = 1.01	0.85
10	0.77 x 1.4 = 1.08	1.0
15	0.82 x 1.4 = 1.15	1.15

$$W_e = W_{ind} + H_T * \gamma_s * B_c * 1.4$$

Original Load on Pipe vs. Load With Geofoam at Different Locations (lbs/ft)

Original	0	5	10	15
8541	10480	12610	14740	16970

Note: A Class III 48 inch pipe can handle Approximately 13,410 lbs/ft with a Type 2 Installation.

ACPA

PipePac

HOME | HELP

Welcome to PipePac

PipePac helps you select the right material for pipelines and culverts and determine the cost of materials over the design life of a project.

Benefits are reliable design information and ease of use based on 20 years of service to designers, specifiers, contractors, purchasers and planners throughout North America and abroad.

The optimal times to apply PipePac are at the planning stage, or when specifications are being drafted to confirm long-term costs of recommended pipe materials, and durability.

PROCEED TO PIPEPAC APPLICATION

3EB
pipe pac
CAPE
LCA

From your **Concrete Pipe association**

Canadian Concrete Pipe & Precast Association
CCPPA
Build on our strength

Ontario Concrete Pipe Association
OCPA
The choice of a lifetime

American Concrete Pipe Association

ACM SOFT
Agility Communication Momentum

TUBÉCON
L'association québécoise des fabricants de tuyaux de béton

ACPA

PipePac

HOME | HELP

Create a project

Load an existing project file Choose File No file chosen LOAD PROJECT



From your **Concrete Pipe association**

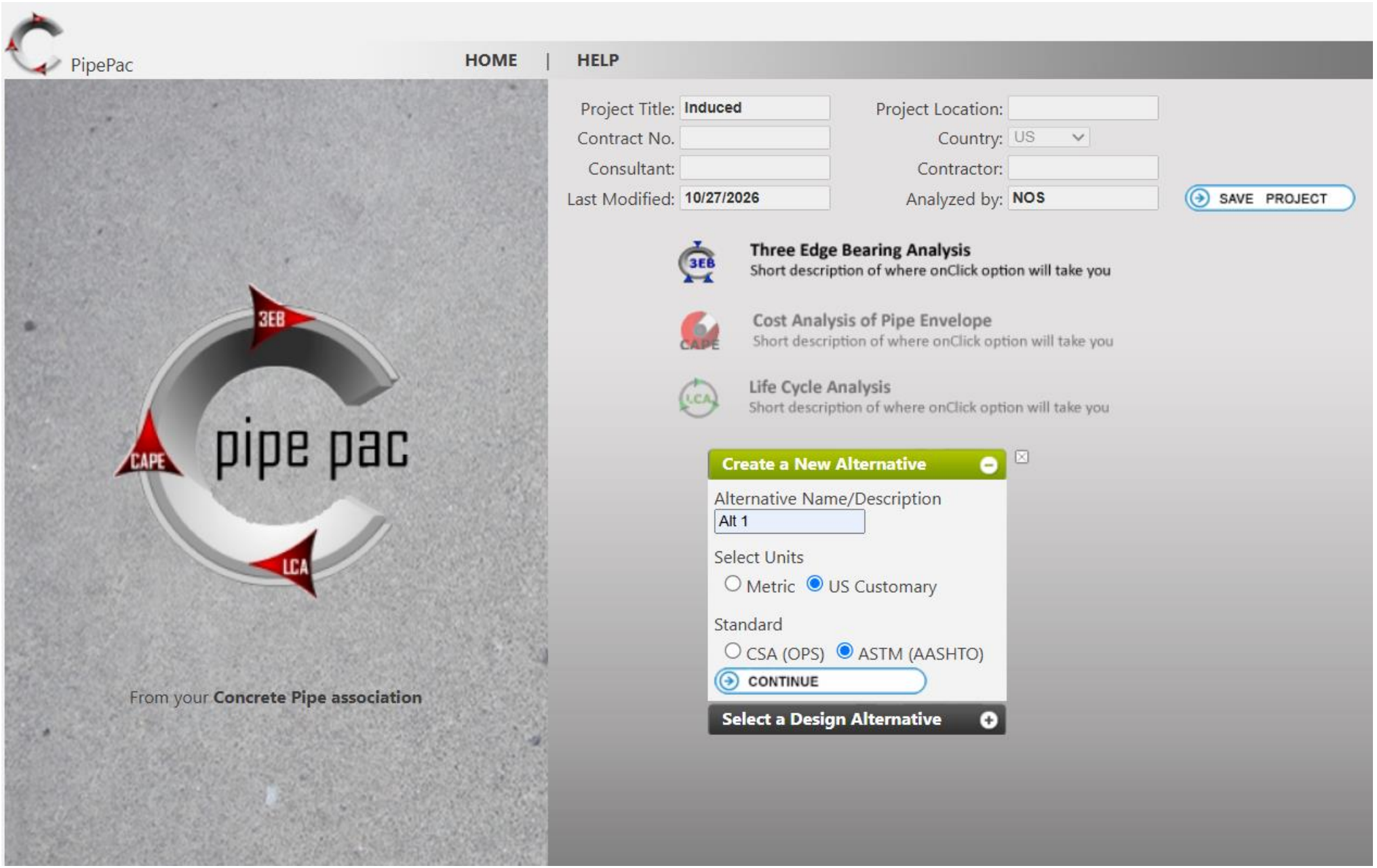
Project Title:	Induced	Project Location:	
Contract No.		Country:	US
Consultant:		Contractor:	
Last Modified:	10/27/2026	Analyzed by:	NOS

SAVE PROJECT

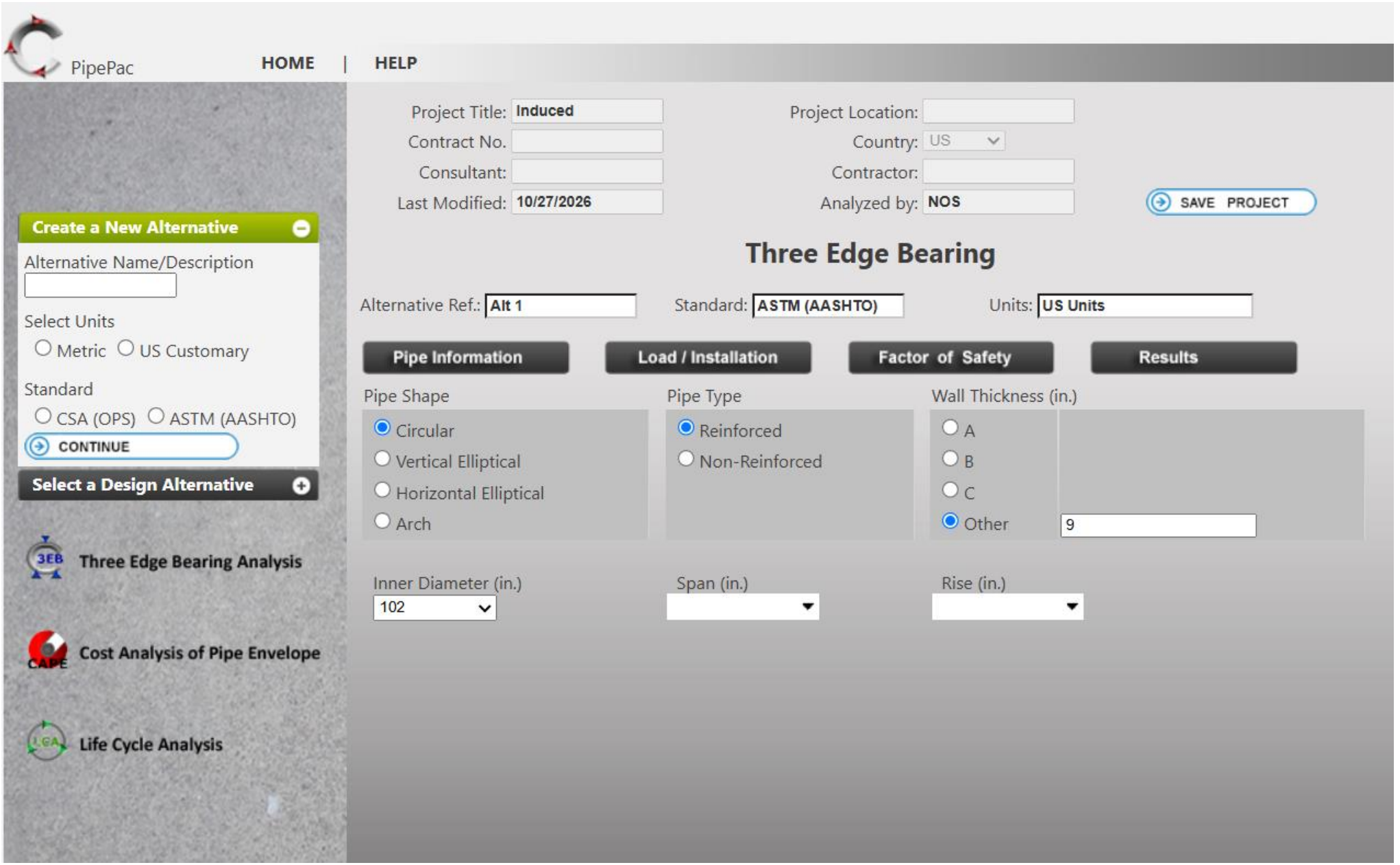
CREATE PROJECT

OCPA Home | ACPA Home | CCPPA Home | Tubécon Home | Liability Agreement

ACPA


PipePac
HOME | HELP
3EB
CAPE
pipe pac
LCA
From your Concrete Pipe association
Project Title: Induced
Contract No.
Consultant:
Last Modified: 10/27/2026
Project Location:
Country: US
Contractor:
Analyzed by: NOS
SAVE PROJECT
Three Edge Bearing Analysis
Short description of where onClick option will take you
Cost Analysis of Pipe Envelope
Short description of where onClick option will take you
Life Cycle Analysis
Short description of where onClick option will take you
Create a New Alternative
Alternative Name/Description
Alt 1
Select Units
Metric
US Customary
Standard
CSA (OPS)
ASTM (AASHTO)
CONTINUE
Select a Design Alternative

ACPA


PipePac
HOME | HELP
Project Title: Induced
Project Location:
Contract No.
Country: US
Consultant:
Contractor:
Last Modified: 10/27/2026
Analyzed by: NOS
SAVE PROJECT
Create a New Alternative
Alternative Name/Description
Select Units
Metric US Customary
Standard
CSA (OPS) ASTM (AASHTO)
CONTINUE
Select a Design Alternative
Three Edge Bearing Analysis
Cost Analysis of Pipe Envelope
Life Cycle Analysis
Three Edge Bearing
Alternative Ref.: Alt 1
Standard: ASTM (AASHTO)
Units: US Units
Pipe Information
Load / Installation
Factor of Safety
Results
Pipe Shape
Circular
Vertical Elliptical
Horizontal Elliptical
Arch
Pipe Type
Reinforced
Non-Reinforced
Wall Thickness (in.)
A
B
C
Other 9
Inner Diameter (in.)
102
Span (in.)
Rise (in.)

HELP

Project Title: Induced
Contract No.
Consultant:
Last Modified: 10/27/2026

Project Location:
Country: US
Contractor:
Analyzed by: NOS

SAVE PROJECT

Three Edge Bearing

Alternative Ref.: Alt 1
Standard: ASTM (AASHTO)
Units: US Units

Pipe Information | Load / Installation | Factor of Safety | Results

Soil Type	Silty Sand
Soil Density (pcf)	120
Vertical Surcharge (psf)	0
Fluid Load	Yes / No

Live Load Type EDIT

AASHTO / CHBDC
Cooper / Other
Aircraft / None

Height of Fill (ft)

Minimum Fill	10.00
Maximum Fill	50.00
Incremental Fill	5.00
Selected Depth	50.0

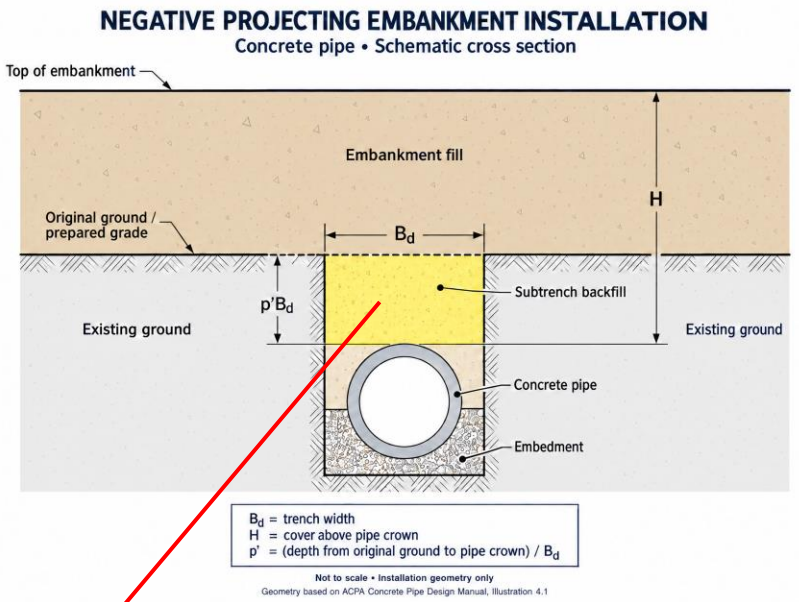
Installation Type EDIT

Trench
Positive Projection
Negative Projection
Jacked or Tunneled

Bedding Type

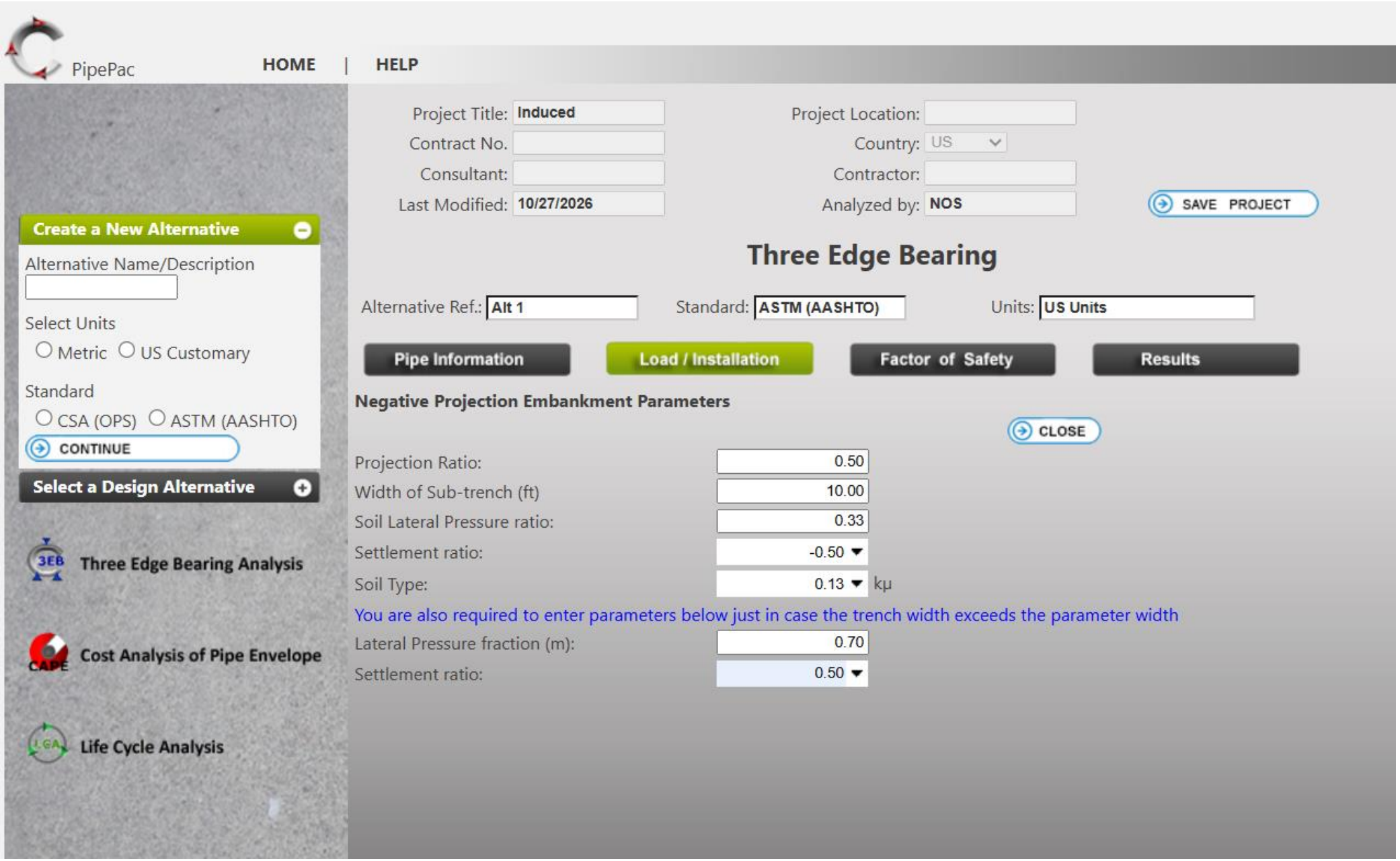
1 / 4
2 / B (Var)
3 / C (Var)
Grouted
Non-Grouted
Other - VAF (Vertical Arching Factor)

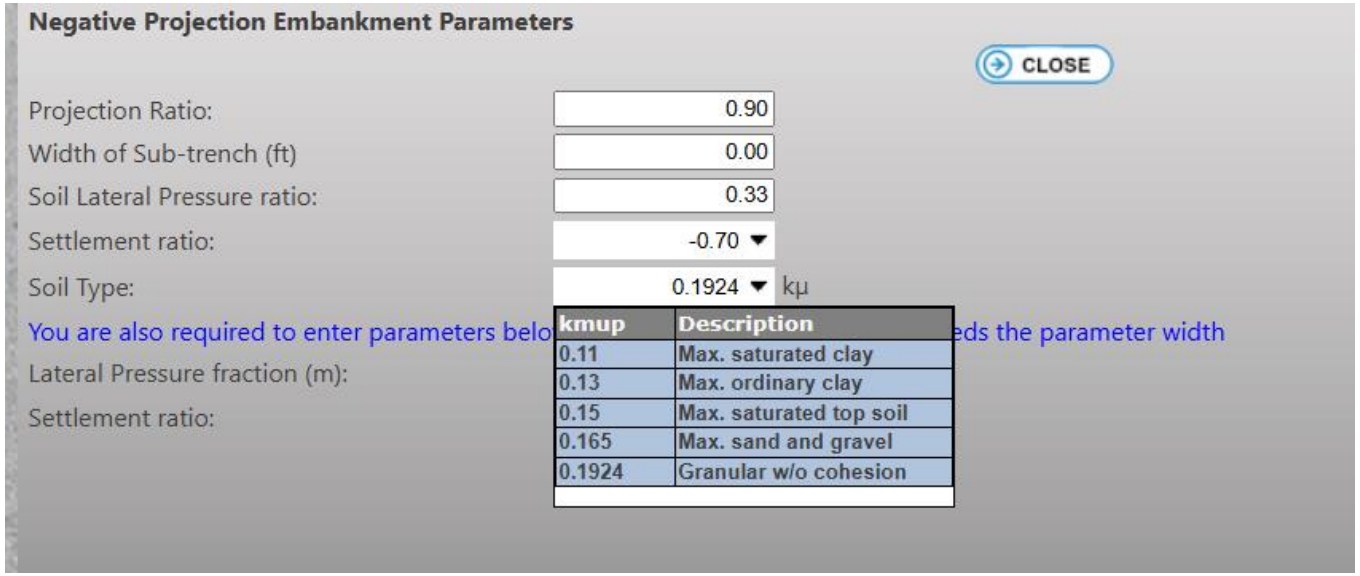
Constant / Variable
Fixed Bedding Factor
Fixed Arching Factor



We are not calculating values for this zone

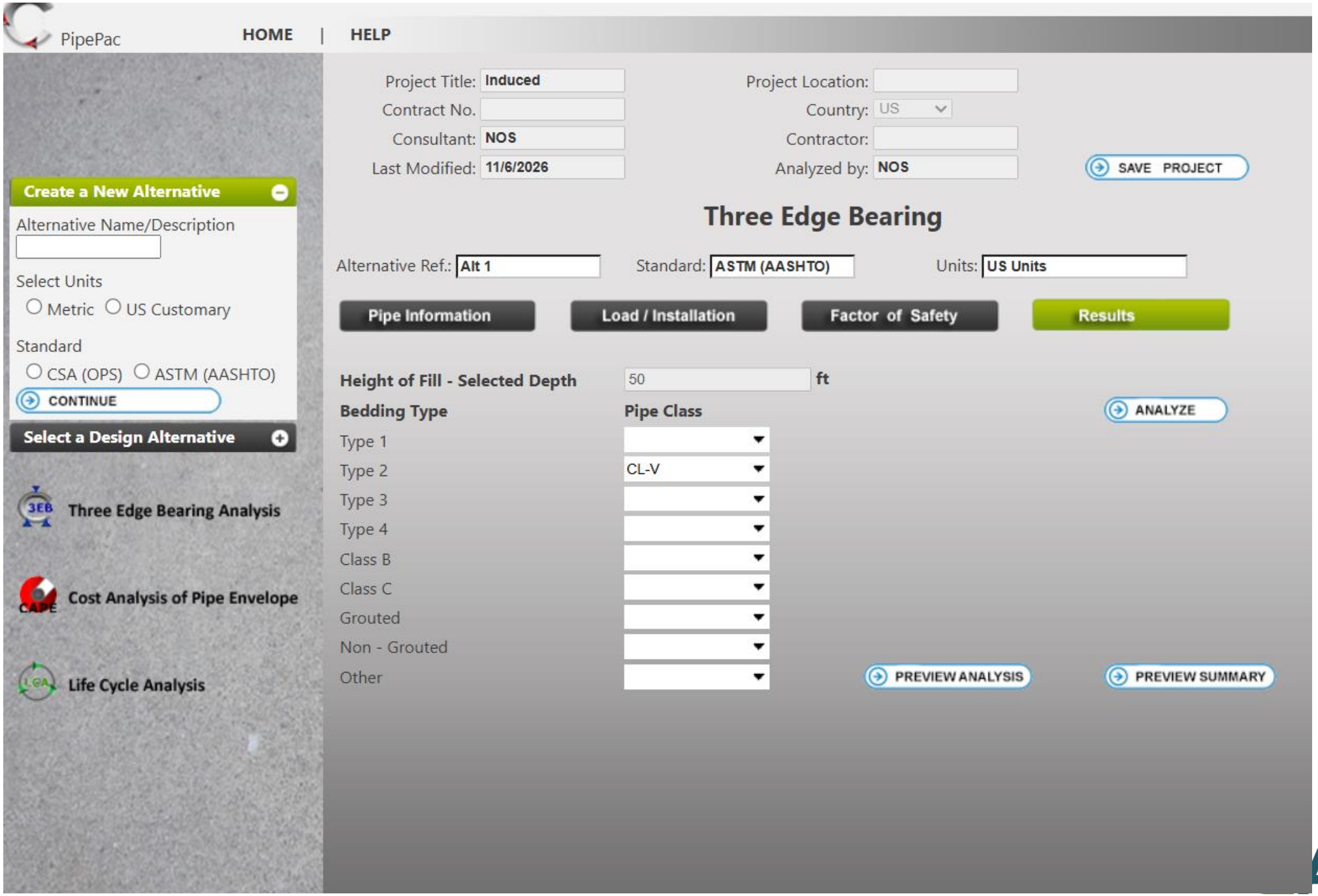
ACPA


PipePac
HOME | HELP
Project Title: Induced
Project Location:
Contract No.
Country: US
Consultant:
Contractor:
Last Modified: 10/27/2026
Analyzed by: NOS
SAVE PROJECT
Create a New Alternative
Alternative Name/Description
Select Units
Metric US Customary
Standard
CSA (OPS) ASTM (AASHTO)
CONTINUE
Select a Design Alternative
Three Edge Bearing Analysis
Cost Analysis of Pipe Envelope
Life Cycle Analysis
Three Edge Bearing
Alternative Ref.: Alt 1
Standard: ASTM (AASHTO)
Units: US Units
Pipe Information
Load / Installation
Factor of Safety
Results
Negative Projection Embankment Parameters
CLOSE
Projection Ratio: 0.50
Width of Sub-trench (ft) 10.00
Soil Lateral Pressure ratio: 0.33
Settlement ratio: -0.50
Soil Type: 0.13 kμ
You are also required to enter parameters below just in case the trench width exceeds the parameter width
Lateral Pressure fraction (m): 0.70
Settlement ratio: 0.50



ϕ	K	μ	Kμ
5	0.840	0.087	0.073
10	0.704	0.176	0.124
15	0.589	0.268	0.158
20	0.490	0.364	0.178
25	0.406	0.466	0.189
30	0.333	0.577	0.192
35	0.271	0.700	0.190
40	0.217	0.839	0.182

ACPA


PipePac
HOME | HELP
Project Title: Induced
Project Location:
Contract No.
Country: US
Consultant: NOS
Contractor:
Last Modified: 11/6/2026
Analyzed by: NOS
SAVE PROJECT
Create a New Alternative
Alternative Name/Description
Select Units
Metric US Customary
Standard
CSA (OPS) ASTM (AASHTO)
CONTINUE
Select a Design Alternative
Three Edge Bearing Analysis
Cost Analysis of Pipe Envelope
Life Cycle Analysis
Three Edge Bearing
Alternative Ref.: Alt 1
Standard: ASTM (AASHTO)
Units: US Units
Pipe Information
Load / Installation
Factor of Safety
Results
Height of Fill - Selected Depth
50
ft
Bedding Type
Pipe Class
ANALYZE
Type 1
Type 2
CL-V
Type 3
Type 4
Class B
Class C
Grouted
Non - Grouted
Other
PREVIEW ANALYSIS
PREVIEW SUMMARY

D-LOAD REQUIREMENTS FOR 102 in. DIAMETER CIRCULAR PIPE

Results of Analysis for Bedding Type 2

Pipe Depth	Arching Factor	>Trans	Earth Load (lb/ft)	Live Load (lb/ft)	Surch Load (lb/ft)	Total Load (lb/ft)	Bed Fact DL	Bed Fact LL	Required D-Load 0.01 in. (lb/ft/ft)
10.00	**0.89**	**N**	**11854**	**0**	**0**	**11854**	**1.90**	**1.90**	**734 (CL-I)**
15.00	**0.84**	**N**	**16193**	**0**	**0**	**16193**	**1.90**	**1.90**	**1003 (CL-III)**
20.00	0.79	N	20002	0	0	20002	1.90	1.90	1239 (CL-III)
25.00	**0.75**	**N**	**23553**	**0**	**0**	**23553**	**1.90**	**1.90**	**1458 (CL-IV)**
30.00	0.74	N	27537	0	0	27537	1.90	1.90	1705 (CL-IV)
35.00	0.73	N	31539	0	0	31539	1.90	1.90	1953 (CL-IV)
40.00	**0.72**	**N**	**35553**	**0**	**0**	**35553**	**1.90**	**1.90**	**2201 (CL-V)**
45.00	0.72	N	39572	0	0	39572	1.90	1.90	2450 (CL-V)
50.00	**0.71**	**N**	**43592**	**0**	**0**	**43592**	**1.90**	**1.90**	**2699 (CL-V)**

ACPA

Compare the 3 Options

Method	Load (lbs/ft)	VAF
Spangler	43,560	0.726
Auburn	46,940	0.766*
KTC	40,200	0.670*

<u>10 foot wide box</u>

H = 50 ft.

E_{geo} = 100 psi

E_{soil} = 2000 psi

r_{sd} = -0.5

Ku = 0.13

P = 0.5

*VAF = Load Ratio * 1.15 for box culvert

Project Title: Induced
Project Location:
Contract No.
Country: US
Consultant: NOS
Contractor:
Last Modified: 11/6/2026
Analyzed by: NOS
SAVE PROJECT

Three Edge Bearing

Alternative Ref.: Alt 1
Standard: ASTM (AASHTO)
Units: US Units

Pipe Information | Load / Installation | Factor of Safety | Results

Negative Projection Embankment Parameters

CLOSE

Projection Ratio:	0.333
Width of Sub-trench (ft)	15.00
Soil Lateral Pressure ratio:	0.33
Settlement ratio:	-0.50
Soil Type:	0.13 kμ

You are also required to enter parameters below just in case the trench width exceeds the parameter width

Lateral Pressure fraction (m):	0.70
Settlement ratio:	0.50

ACPA

D-LOAD REQUIREMENTS FOR 102 in. DIAMETER CIRCULAR PIPE
Results of Analysis for Bedding Type 2

Pipe Depth	Arching Factor	>Trans	Earth Load (lb/ft)	Live Load (lb/ft)	Surch Load (lb/ft)	Total Load (lb/ft)	Bed Fact DL	Bed Fact LL	Required D-Load 0.01 in. (lb/ft/ft)
10.00	**1.34**	**N**	**17814**	**0**	**0**	**17814**	**2.57**	**2.20**	**815 (CL-II)**
15.00	**1.30**	**N**	**25063**	**0**	**0**	**25063**	**2.56**	**2.20**	**1150 (CL-III)**
20.00	**1.25**	**N**	**31710**	**0**	**0**	**31710**	**2.54**	**2.20**	**1471 (CL-IV)**
25.00	1.21	N	37806	0	0	37806	2.50	2.20	1776 (CL-IV)
30.00	**1.18**	**N**	**43846**	**0**	**0**	**43846**	**2.47**	**2.20**	**2086 (CL-V)**
35.00	1.16	N	50404	0	0	50404	2.44	2.20	2426 (CL-V)
40.00	1.16	N	56980	0	0	56980	2.42	2.20	2773 (CL-V)
45.00	**1.15**	**N**	**63578**	**0**	**0**	**63578**	**2.39**	**2.20**	**3125 (3125-D)**
50.00	**1.15**	**N**	**70181**	**0**	**0**	**70181**	**2.37**	**2.20**	**3482 (3482-D)**

$$70181 \text{ lbs/ft} \times \frac{10 \text{ ft.}}{15 \text{ ft.}} = 46787 \text{ lbs/ft}$$

PL = 120 pcf x 10 ft x 50 ft = 60,000 lbs/ft

$$VAF = \frac{46787 \text{ lbs/ft}}{60000 \text{ lbs/ft}} = 0.78$$

$$Red = 1 - \frac{46787 \text{ lbs/ft}}{60000 \text{ lbs/ft} \times 1.15} = 32\%$$

Bd (Width of Soft Material) (ft)	Soil Load - Rigid Pipe (lbs/ft)	Soil Load - Flexible Pipe (lbs/ft)
10 ft.	43,560	43,560
11 ft.	48,780	44,460
12 ft.	54,020	45,230
13 ft.	59,350	45,950
14 ft.	64,710	46,590
15 ft.	70,090	47,160

CPA

The Use of Lightweight Fill with Buried Structures

- Lightweight Materials can be used as a one-to-one substitution for standard backfill materials to reduce the load on a buried structure.
- Lightweight Materials can be used with soil-structure interaction to reduce the load on an initially buried structure, or allow additional soil to be placed over an existing structure.
- There are several methods available in which to perform the design for an induced trench, but there results should be similar.

The End

jbeakley@concretepipe.org