Josh Beakley

BOXCAR

Introduction

BOXCAR

Version 3.0.42 for Windows
1 September 2010

A Computer Program for the Structural Design of Reinforced Concrete Box Culverts

Developed by
Simpson Gumpertz & Heger Inc.

In cooperation with

The Federal Highway Administration
and
The American Concrete Pipe Association

SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

American Concrete Pipe Association

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

Continue

Boxcar

WARNING!

****

The successful application and use of this software product is dependent on the application of skilled engineering judgment and is the responsibility of the user. The user must select input values suitable to his specific installation. The information presented in the computer output is for review, interpretation, application and approval by a qualified engineer.

****

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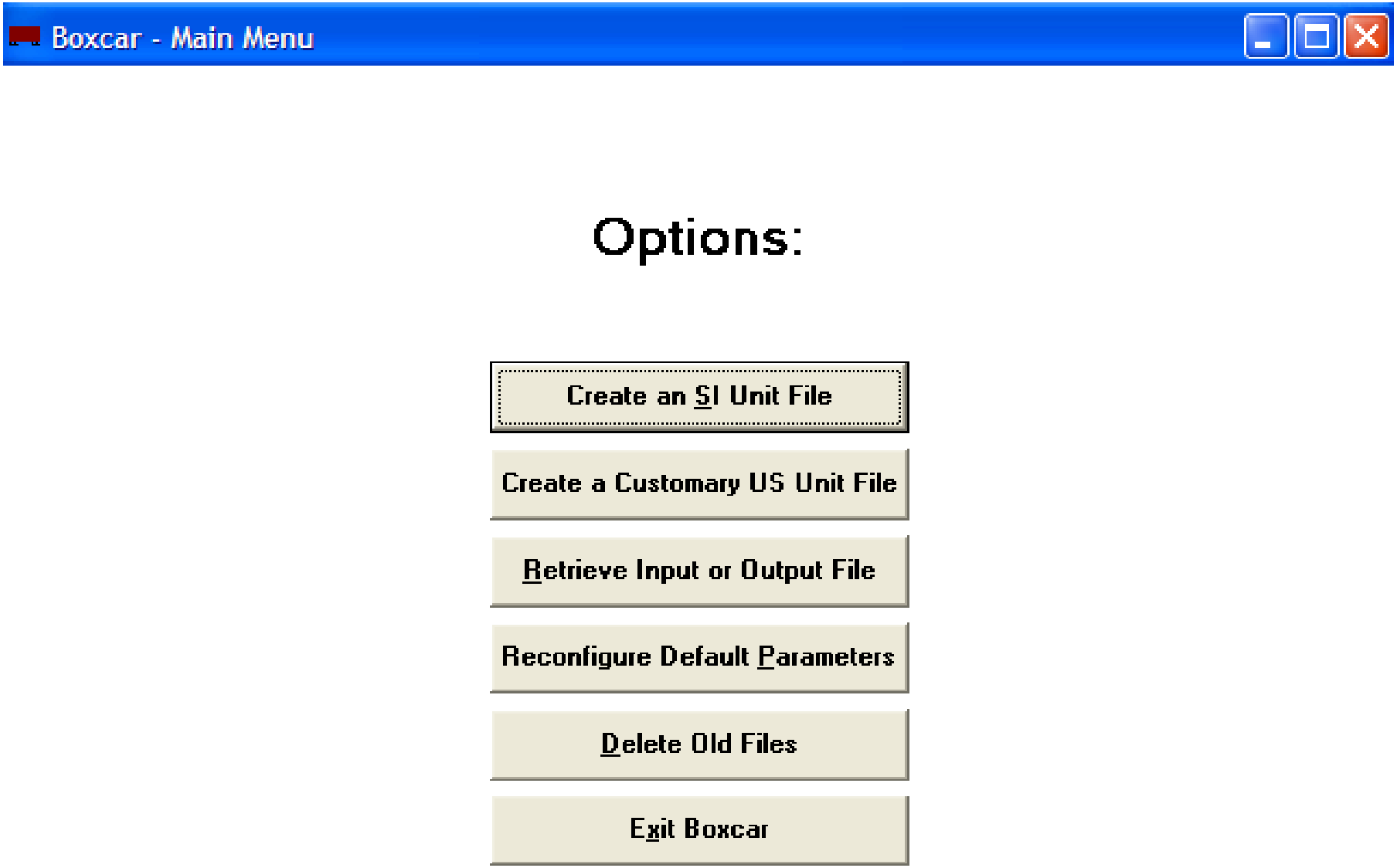
Continue

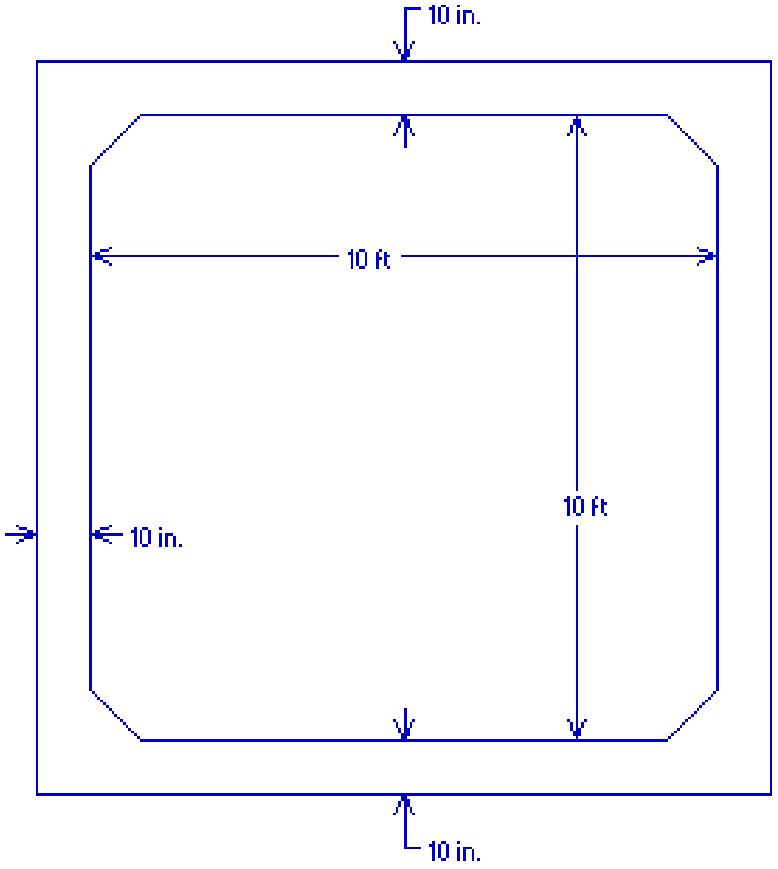

Boxcar - Main Menu
Options:
Create an SI Unit File
Create a Customary US Unit File
Retrieve Input or Output File
Reconfigure Default Parameters
Delete Old Files
Exit Boxcar

Boxcar - Design (page 1)

Filename: Pipe School .box ?

Job Description: Example

Span:	10	ft
Rise:	10	ft
Min. Depth of Fill:	0	ft
Max. Depth of Fill:	0	ft
Depth Increment:	0	ft
Length of precast section:	8	ft



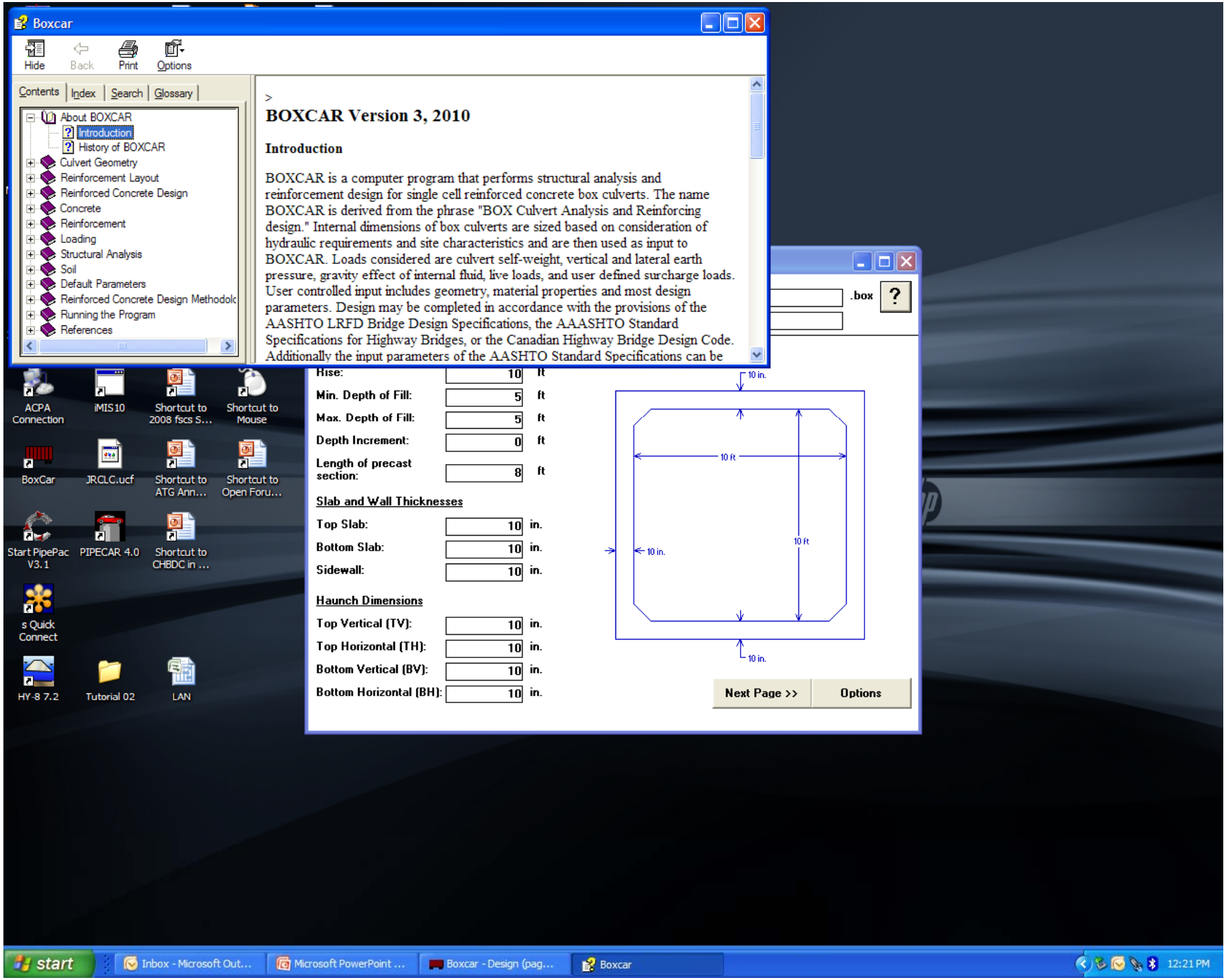
Slab and Wall Thicknesses

Top Slab:	10	in.
Bottom Slab:	10	in.
Sidewall:	10	in.

Haunch Dimensions

Top Vertical (TV):	10	in.
Top Horizontal (TH):	10	in.
Bottom Vertical (BV):	10	in.
Bottom Horizontal (BH):	10	in.

Next Page >> Options


Boxcar
Hide
Back
Print
Options
Contents
Index
Search
Glossary
About BOXCAR
Introduction
History of BOXCAR
Culvert Geometry
Reinforcement Layout
Reinforced Concrete Design
Concrete
Reinforcement
Loading
Structural Analysis
Soil
Default Parameters
Reinforced Concrete Design Methodolc
Running the Program
References
BOXCAR Version 3, 2010
Introduction
BOXCAR is a computer program that performs structural analysis and reinforcement design for single cell reinforced concrete box culverts. The name BOXCAR is derived from the phrase "BOX Culvert Analysis and Reinforcing design." Internal dimensions of box culverts are sized based on consideration of hydraulic requirements and site characteristics and are then used as input to BOXCAR. Loads considered are culvert self-weight, vertical and lateral earth pressure, gravity effect of internal fluid, live loads, and user defined surcharge loads. User controlled input includes geometry, material properties and most design parameters. Design may be completed in accordance with the provisions of the AASHTO LRFD Bridge Design Specifications, the AAASHTO Standard Specifications for Highway Bridges, or the Canadian Highway Bridge Design Code. Additionally the input parameters of the AASHTO Standard Specifications can be
.box
?
Rise: 10 ft
Min. Depth of Fill: 5 ft
Max. Depth of Fill: 5 ft
Depth Increment: 0 ft
Length of precast section: 8 ft
Slab and Wall Thicknesses
Top Slab: 10 in.
Bottom Slab: 10 in.
Sidewall: 10 in.
Haunch Dimensions
Top Vertical (TV): 10 in.
Top Horizontal (TH): 10 in.
Bottom Vertical (BV): 10 in.
Bottom Horizontal (BH): 10 in.
10 in.
10 ft
10 ft
10 in.
10 in.
Next Page >>
Options
ACPA Connection
iMIS10
Shortcut to 2008 fscs S...
Shortcut to Mouse
BoxCar
JRCLC.ucf
Shortcut to ATG Ann...
Shortcut to Open Foru...
Start PipePac V3.1
PIPECAR 4.0
Shortcut to CHBDC in ...
s Quick Connect
HY-8 7.2
Tutorial 02
LAN
start
Inbox - Microsoft Out...
Microsoft PowerPoint ...
Boxcar - Design (pag...
Boxcar
12:21 PM

Boxcar - Design (page 2)

Design Code	AASHTO - LRFD	?
Load Factors	AASHTO - LRFD	View
Load Combinations	AASHTO - LRFD	View
Axial Thrust Load Factor	User Specified	1
Load Modifiers	Edit	
Strength Reduction Factors	Design Code	

Flexure 1 Shear 0.9

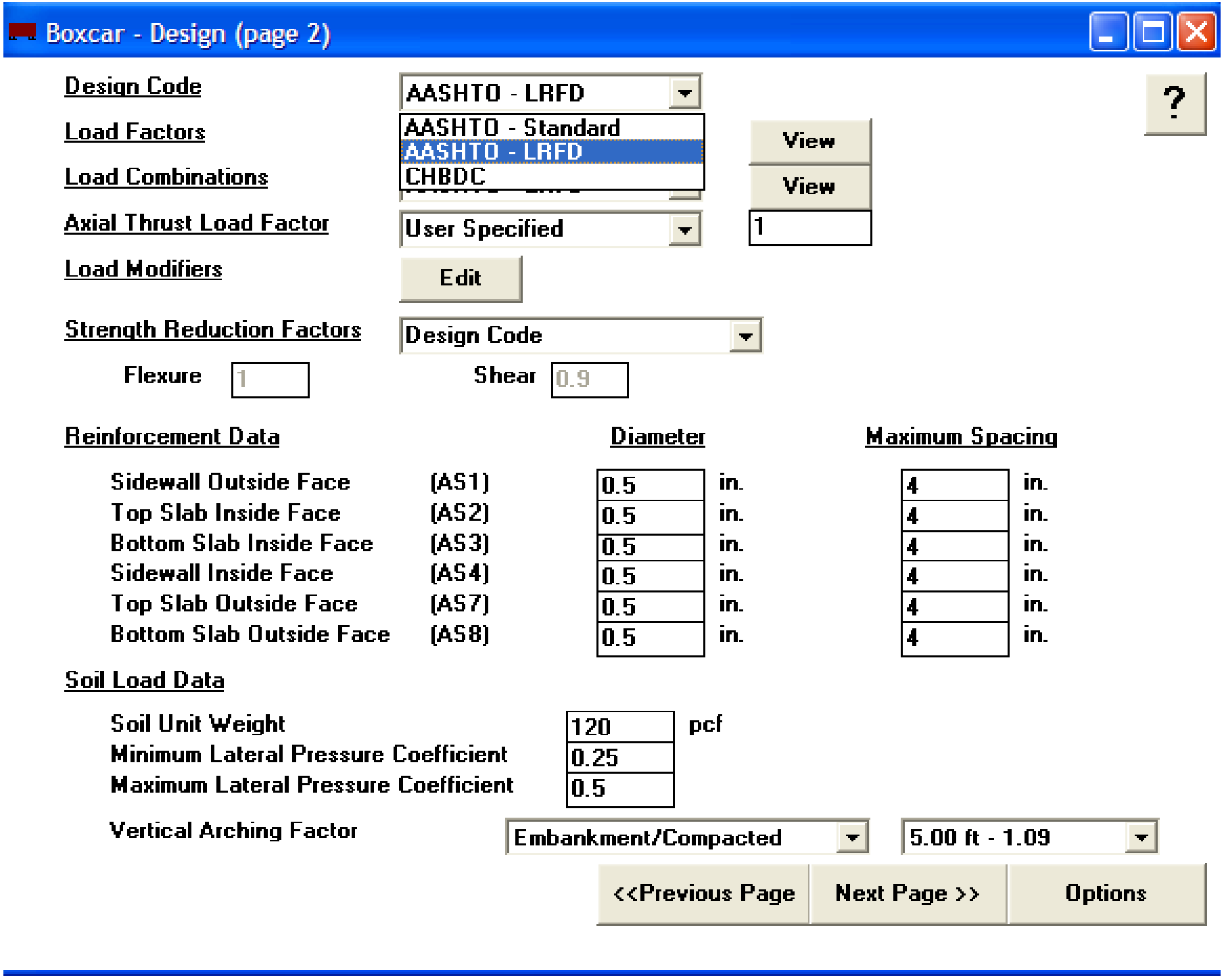
Reinforcement Data		Diameter		Maximum Spacing	
Sidewall Outside Face	(AS1)	0.5	in.	4	in.
Top Slab Inside Face	(AS2)	0.5	in.	4	in.
Bottom Slab Inside Face	(AS3)	0.5	in.	4	in.
Sidewall Inside Face	(AS4)	0.5	in.	4	in.
Top Slab Outside Face	(AS7)	0.5	in.	4	in.
Bottom Slab Outside Face	(AS8)	0.5	in.	4	in.

Soil Load Data

Soil Unit Weight	120	pcf
Minimum Lateral Pressure Coefficient	0.25	
Maximum Lateral Pressure Coefficient	0.5	

Vertical Arching Factor: Embankment/Compacted — 5.00 ft - 1.09

<<Previous Page | Next Page >> | Options


Boxcar - Design (page 2)
Design Code
AASHTO - LRFD
AASHTO - Standard
AASHTO - LRFD
CHBDC
?
Load Factors
View
Load Combinations
View
Axial Thrust Load Factor
User Specified
1
Load Modifiers
Edit
Strength Reduction Factors
Design Code
Flexure
1
Shear
0.9
Reinforcement Data
Diameter
Maximum Spacing
Sidewall Outside Face (AS1) 0.5 in. 4 in.
Top Slab Inside Face (AS2) 0.5 in. 4 in.
Bottom Slab Inside Face (AS3) 0.5 in. 4 in.
Sidewall Inside Face (AS4) 0.5 in. 4 in.
Top Slab Outside Face (AS7) 0.5 in. 4 in.
Bottom Slab Outside Face (AS8) 0.5 in. 4 in.
Soil Load Data
Soil Unit Weight 120 pcf
Minimum Lateral Pressure Coefficient 0.25
Maximum Lateral Pressure Coefficient 0.5
Vertical Arching Factor
Embankment/Compacted
5.00 ft - 1.09
<<Previous Page
Next Page >>
Options

Boxcar - Design (page 2)

Design Code: AASHTO - LRFD

Load Factors: AASHTO - LRFD — View

Load Combinations: AASHTO - LRFD / User Defined — View

Axial Thrust Load Factor: User Specified — 1

Load Modifiers: Edit

Strength Reduction Factors: Design Code

Flexure: 1 Shear: 0.9

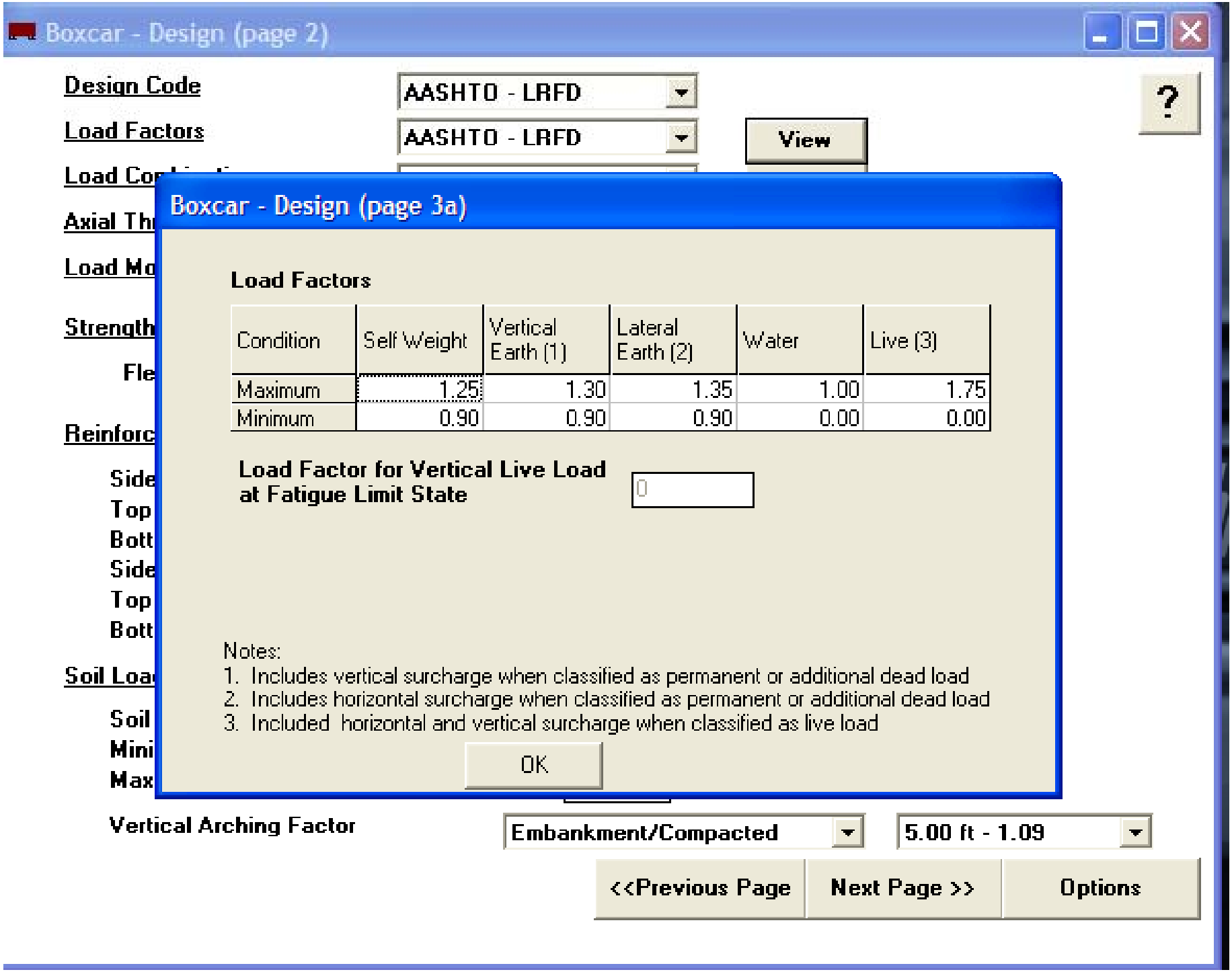
Reinforcement Data		Diameter		Maximum Spacing	
Sidewall Outside Face	(AS1)	0.5	in.	4	in.
Top Slab Inside Face	(AS2)	0.5	in.	4	in.
Bottom Slab Inside Face	(AS3)	0.5	in.	4	in.
Sidewall Inside Face	(AS4)	0.5	in.	4	in.
Top Slab Outside Face	(AS7)	0.5	in.	4	in.
Bottom Slab Outside Face	(AS8)	0.5	in.	4	in.

Soil Load Data

Soil Unit Weight	120	pcf
Minimum Lateral Pressure Coefficient	0.25	
Maximum Lateral Pressure Coefficient	0.5	

Vertical Arching Factor: Embankment/Compacted — 5.00 ft - 1.09

<<Previous Page | Next Page >> | Options


Boxcar - Design (page 2)
Design Code
AASHTO - LRFD
Load Factors
AASHTO - LRFD
View
?
Boxcar - Design (page 3a)
Load Factors
Condition | Self Weight | Vertical Earth (1) | Lateral Earth (2) | Water | Live (3)
Maximum | 1.25 | 1.30 | 1.35 | 1.00 | 1.75
Minimum | 0.90 | 0.90 | 0.90 | 0.00 | 0.00
Load Factor for Vertical Live Load at Fatigue Limit State
0
Notes:
1. Includes vertical surcharge when classified as permanent or additional dead load
2. Includes horizontal surcharge when classified as permanent or additional dead load
3. Included horizontal and vertical surcharge when classified as live load
OK
Vertical Arching Factor
Embankment/Compacted
5.00 ft - 1.09
<<Previous Page
Next Page >>
Options

Boxcar - Design (page 2)

Design Code: AASHTO - LRFD

Load Factors: AASHTO - LRFD — View

Load Combinations: AASHTO - LRFD — View

Axial Thrust Load Factor: AASHTO - LRFD / User Defined — 1

Load Modifiers: Edit

Strength Reduction Factors: Design Code

Flexure: 1 Shear: 0.9

Reinforcement Data		Diameter		Maximum Spacing	
Sidewall Outside Face	(AS1)	0.5	in.	4	in.
Top Slab Inside Face	(AS2)	0.5	in.	4	in.
Bottom Slab Inside Face	(AS3)	0.5	in.	4	in.
Sidewall Inside Face	(AS4)	0.5	in.	4	in.
Top Slab Outside Face	(AS7)	0.5	in.	4	in.
Bottom Slab Outside Face	(AS8)	0.5	in.	4	in.

Soil Load Data

Soil Unit Weight	120 pcf
Minimum Lateral Pressure Coefficient	0.25
Maximum Lateral Pressure Coefficient	0.5

Vertical Arching Factor: Embankment/Compacted — 5.00 ft - 1.09

<<Previous Page | Next Page >> | Options

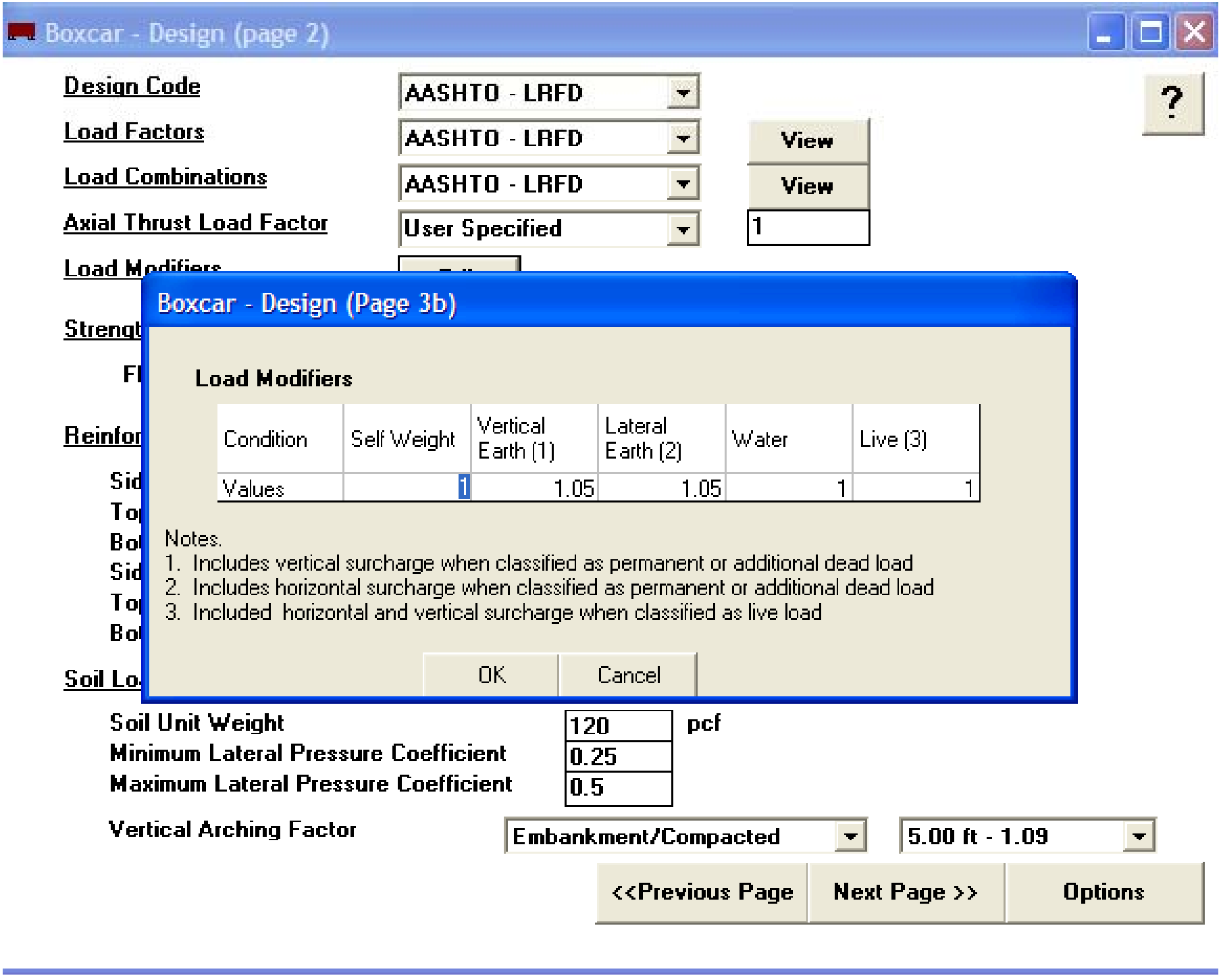
BOXCAR - Design (page 3c)

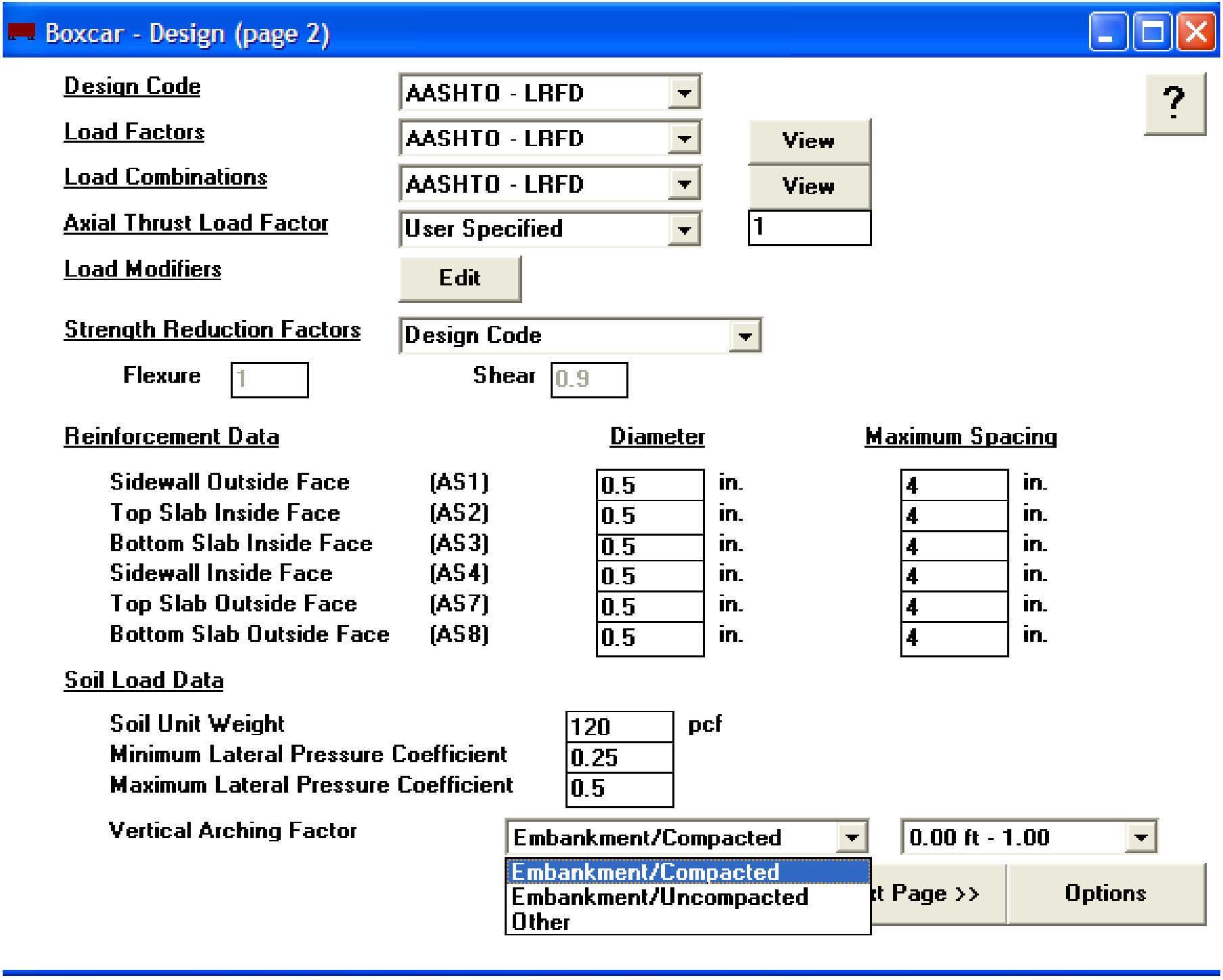
Load Combination

Load Comb	Default Purpose (3)	Self Weight	Vertical Earth Press	Lateral Earth Press	Internal Fluid	Vertical Live	Appr. Live	Surcharge Conditions (1)	Vertical Surcharge	Horizontal Surcharge
1	MaxV/Ma	Max	Max	Max	0.00	Max	Max	A	Max	Max
2	MaxV/Mir	Max	Max	Min	Max	Max	0.00	A	Max	0.00
3	MinV/Max	Min	Min	Max	0.00	0.00	Max	A	0.00	Max
4	Fatigue (2)					0				

Notes: 1. The surcharge condition can be set as Permanent (P), Additional (A), or Live (L), and must be the same for all cases.
2. The last load combination is reserved for Fatigue. The Load Factor for the Fatigue is set on the Load Factor Page. <Delete Row> (when available) deletes the second to last row.
3. The default purpose is limited to 14 characters.

OK | Add Row | Remove Row


Boxcar - Design (page 2)
Design Code
AASHTO - LRFD
Load Factors
AASHTO - LRFD
View
Load Combinations
AASHTO - LRFD
View
Axial Thrust Load Factor
User Specified
1
Load Modifiers
Boxcar - Design (Page 3b)
Load Modifiers
Condition
Self Weight
Vertical Earth (1)
Lateral Earth (2)
Water
Live (3)
Values
1
1.05
1.05
1
1
Notes.
1. Includes vertical surcharge when classified as permanent or additional dead load
2. Includes horizontal surcharge when classified as permanent or additional dead load
3. Included horizontal and vertical surcharge when classified as live load
OK
Cancel
Soil Unit Weight
120
pcf
Minimum Lateral Pressure Coefficient
0.25
Maximum Lateral Pressure Coefficient
0.5
Vertical Arching Factor
Embankment/Compacted
5.00 ft - 1.09
<<Previous Page
Next Page >>
Options


Boxcar - Design (page 2)
Design Code
AASHTO - LRFD
?
Load Factors
AASHTO - LRFD
View
Load Combinations
AASHTO - LRFD
View
Axial Thrust Load Factor
User Specified
1
Load Modifiers
Edit
Strength Reduction Factors
Design Code
Flexure
1
Shear
0.9
Reinforcement Data
Diameter
Maximum Spacing
Sidewall Outside Face (AS1) 0.5 in. 4 in.
Top Slab Inside Face (AS2) 0.5 in. 4 in.
Bottom Slab Inside Face (AS3) 0.5 in. 4 in.
Sidewall Inside Face (AS4) 0.5 in. 4 in.
Top Slab Outside Face (AS7) 0.5 in. 4 in.
Bottom Slab Outside Face (AS8) 0.5 in. 4 in.
Soil Load Data
Soil Unit Weight 120 pcf
Minimum Lateral Pressure Coefficient 0.25
Maximum Lateral Pressure Coefficient 0.5
Vertical Arching Factor
Embankment/Compacted
0.00 ft - 1.00
Embankment/Compacted
Embankment/Uncompacted
Other
t Page >>
Options

Boxcar - Design (page 3)

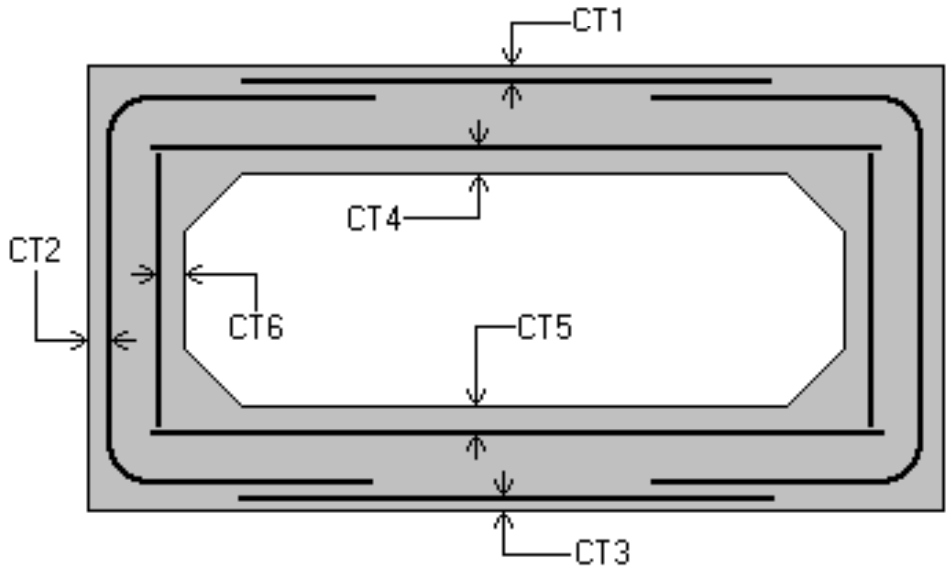
?

Outside Clear Concrete Cover

Top	(CT1)	2	in.
Bottom	(CT3)	1	in.
Side	(CT2)	1	in.

Inside Clear Concrete Cover

Top	(CT4)	1	in.
Bottom	(CT5)	1	in.
Side	(CT6)	1	in.



Material Properties

Main Reinforcement Yield Strength (Fy)	65000	psi
Total Service Stress Limit	100	% Fy
Design Concrete Strength	5000	psi
Concrete Unit Weight	150	pcf

<<Previous Page | Next Page >> | Options

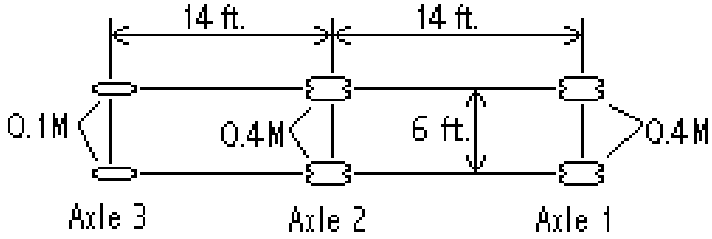
Boxcar - Design (page 4) | HS-Series

Live Load Data

Live Load Type (Max 2)	Magnitude (M)	
☑ HS-Series	20	tons
☑ Interstate/Tandem	25	kips
☐ Cooper Series		kips
☐ CHBDC Truck		kips
☐ Tandem/Tridem		kips
☐ Other		kips
☐ None		

?

AASHTO HS Truck Wheel Layout



Magnitude(M) = Combined Weight of axles 2 and 3

Direction of Traffic: Parallel — To Span

Impact Factor Options: Design Code

Impact Factor: Design

Tire Footprint: HS-Series: Design Code

Tire Footprint Length: 10 in.

Tire Footprint Width: 20 in.

Lane Load: 0 lb/ft

Live Load Distribution Factor (LLDF): Design Code — 1.15

Surcharge Loads

Uniform Vertical	0	lb/ft
Lateral - Top of Culvert (LLTC)	0	lb/ft
Lateral - Bottom of Culvert (LLBC)	0	lb/ft

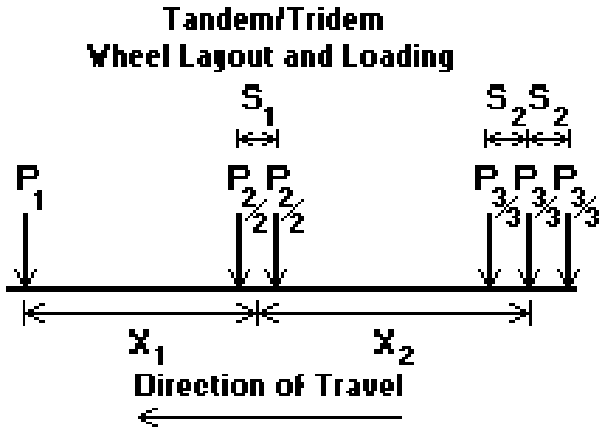
Fluid Loads

Depth of Fluid	10	ft
Fluid Unit Weight	62.5	pcf

<<Previous Page | Next Page>> | Options

Boxcar - Design (Page 4a)

Tandem/Tridem Load Configuration



Loads

Gross Vehicle Magnitude (M)	140	kips
Load Fraction P1	0.1	
Load Fraction P2	0.5	
Load Fraction P3	0.4	

Applied load at Axle Group "X" = M * Px
Applied load at Wheel Group "X" = M * Px/2

Spacings

Spacing X1	20	ft
Spacing X2	20	ft
Wheel Pitch S1	4	ft
Wheel Pitch S2	4	ft
Wheel Base (Width)	6	ft

OK

Boxcar - Design (page 5)

?

Stirrup Data

Provide stirrup spacing and material
properties to be used if stirrups are required

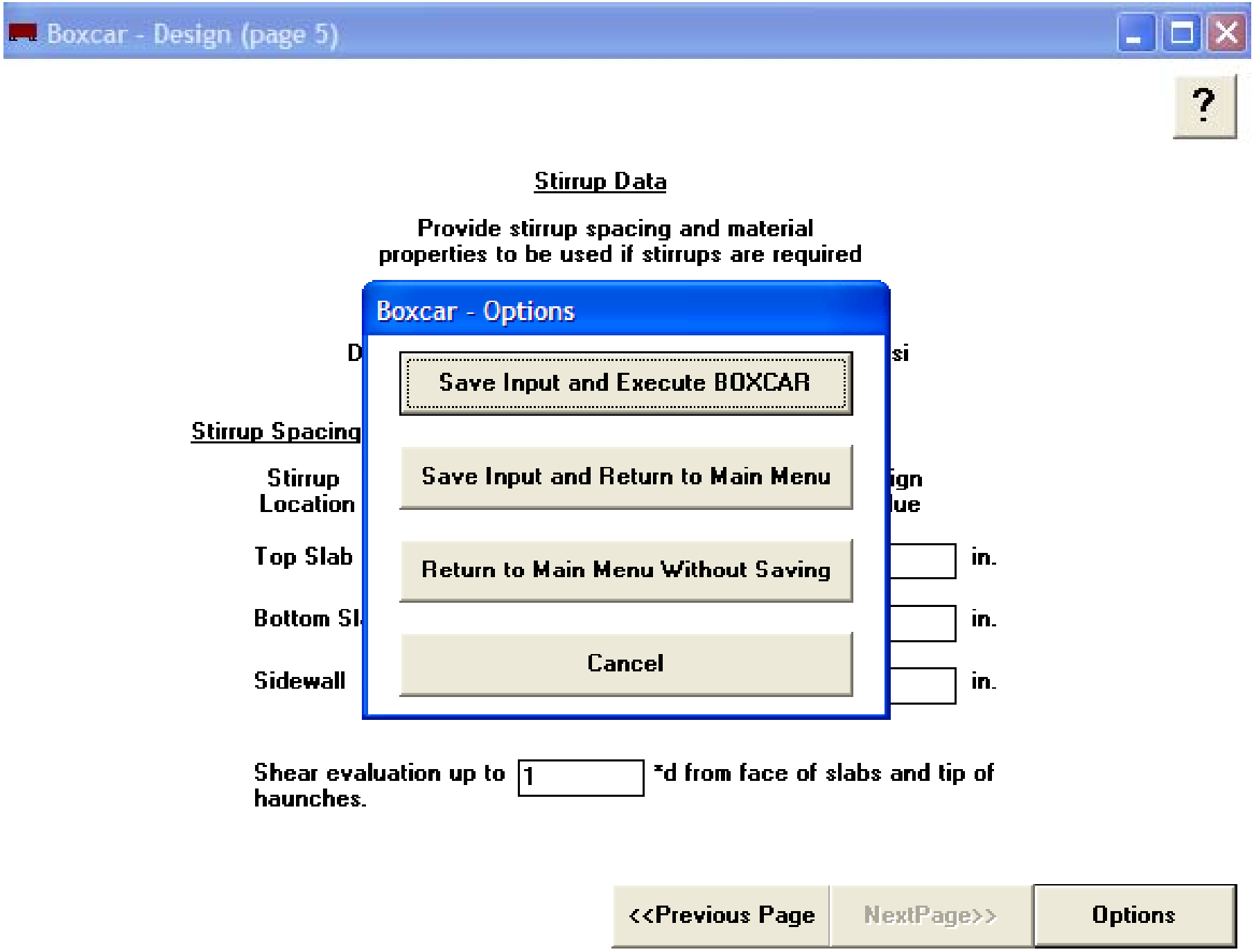
Developable stirrup yield stress 60000 psi

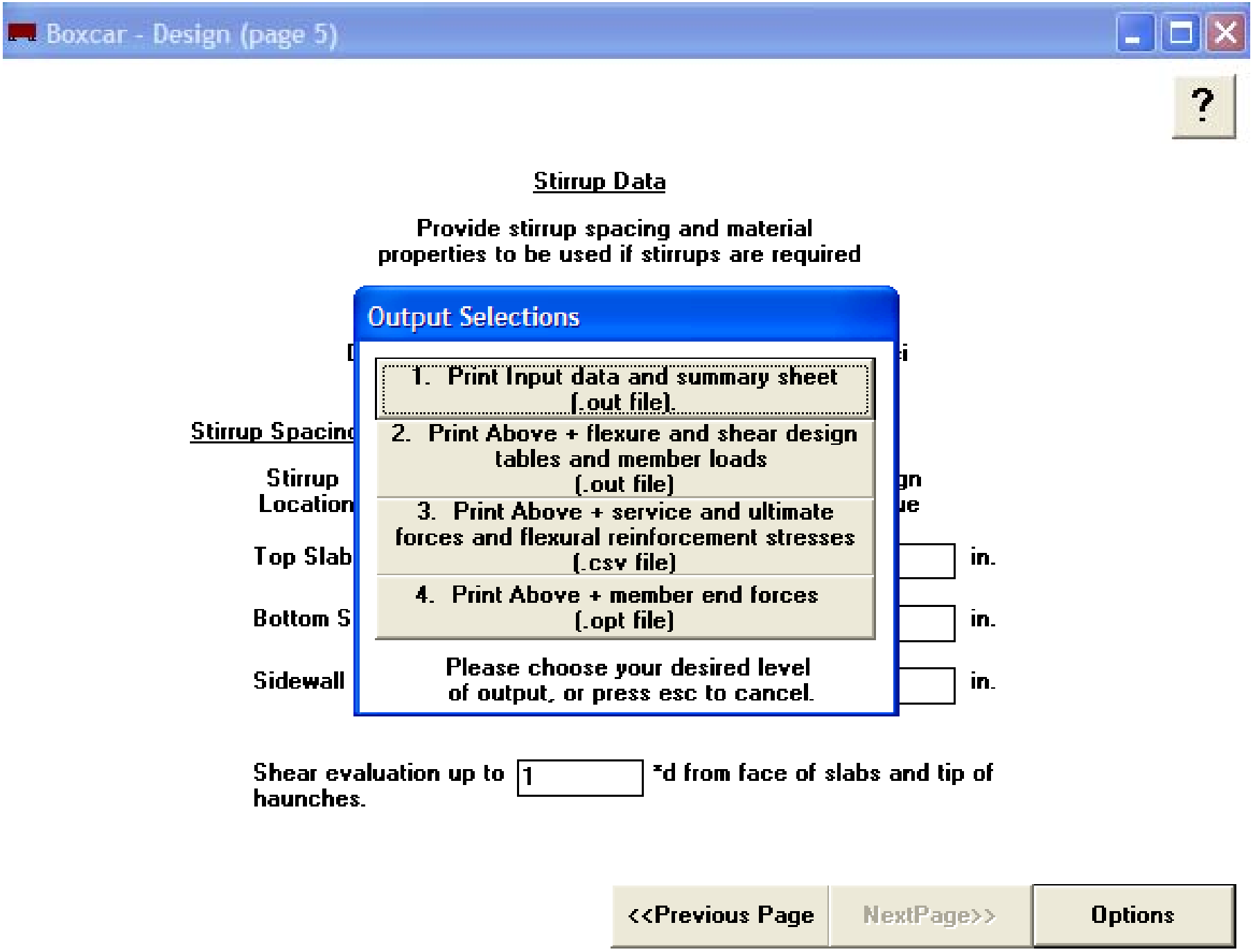
Stirrup Spacing

Stirrup Location	Maximum Allowable	Design Value
Top Slab	4.00 in.	3.5 in.
Bottom Slab	4.50 in.	4 in.
Sidewall	4.38 in.	4 in.

Shear evaluation up to 1 *d from face of slabs and tip of haunches.

<<Previous Page | NextPage>> | Options


Boxcar - Design (page 5)
?
Stirrup Data
Provide stirrup spacing and material
properties to be used if stirrups are required
Boxcar - Options
Save Input and Execute BOXCAR
Save Input and Return to Main Menu
Return to Main Menu Without Saving
Cancel
Stirrup Spacing
Stirrup
Location
Top Slab
Bottom Sl
Sidewall
in.
in.
in.
Shear evaluation up to
1
*d from face of slabs and tip of
haunches.
<<Previous Page
NextPage>>
Options


Boxcar - Design (page 5)
?
Stirrup Data
Provide stirrup spacing and material properties to be used if stirrups are required
Output Selections
1. Print Input data and summary sheet (.out file).
2. Print Above + flexure and shear design tables and member loads (.out file)
3. Print Above + service and ultimate forces and flexural reinforcement stresses (.csv file)
4. Print Above + member end forces (.opt file)
Please choose your desired level of output, or press esc to cancel.
Stirrup Spacing
Stirrup Location
Top Slab
Bottom S
Sidewall
in.
in.
in.
Shear evaluation up to 1 *d from face of slabs and tip of haunches.
<<Previous Page
NextPage>>
Options

BOXCAR

Version 3.0.42 for Windows
1 September 2010

A Computer Program for the Structural
Design of Reinforced Concrete Box
Culverts

Developed by

Simpson Gumpertz & Heger Inc.
in cooperation with

The Federal Highway Administration
and
The American Concrete Pipe Association

The successful application and use of this software product is dependent on the application of skilled engineering judgment and is the responsibility of the user. The user must select input values suitable to his specific installation. The information presented in the computer output is for review, interpretation, application and approval by a qualified engineer.

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ANY IMPLIED OR EXPRESS WARRANTIES COVERING THE SOFTWARE PROGRAM OR PROGRAM USER MANUAL INCLUDING ANY WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY EXCLUDED. SIMPSON GUMPERTZ & HEGER INC., THE AMERICAN CONCRETE PIPE ASSOCIATION, AND THE FEDERAL HIGHWAY ADMINISTRATION SHALL NOT BE LIABLE FOR SPECIAL, INCIDENTAL, CONSEQUENTIAL INDIRECT OR OTHER SIMILAR DAMAGES ARISING FROM BREACH OF WARRANTY, BREACH OF CONTRACT OR OTHER LEGAL THEORY EVEN IF SUCH PARTIES HAVE BEEN ADVISED OF SUCH DAMAGES.

****

Date: 11-10-2010
Time: 08:33:25
Filename - Pipe School

Filename - Pipe School
Job Description - Example

GEOMETRY

Span	10. ft	Top Slab Thickness	10. in.
Rise	10. ft	Bottom Slab Thickness	10. in.
Min. Depth of Fill	0. ft	Sidewall Thickness	10. in.
Max. Depth of Fill	0. ft	Length of Precast Section	8. ft
Depth Increment	0. ft		

HAUNCH DIMENSIONS		CONCRETE COVERS	
Top Vertical	10. in.	Top Outside	2.00 in.
Top Horizontal	10. in.	Bottom Outside	1.00 in.
Bottom Vertical	10. in.	Sidewall Outside	1.00 in.
Bottom Horizontal	10. in.	Top Inside	1.00 in.
		Bottom Inside	1.00 in.
		Sidewall Inside	1.00 in.

MATERIAL PROPERTIES

Main Reinforcing Yield Stress	65000. psi
Total Service Stress Limit, % of Yield Stress	100 %
Design Concrete Strength	5000. psi
Concrete Density	150. pcf

DESIGN SPECIFICATION: AASHTO LRFD

REINFORCING DATA

	DIAMETER	SPACING
Top Slab Outside Face(AS7)	0.5 in.	4 in.
Bottom Slab Outside Face(AS8)	0.5 in.	4 in.
Sidewall Outside Face(AS1)	0.5 in.	4 in.
Top Slab Inside Face(AS2)	0.5 in.	4 in.
Bottom Slab Inside Face(AS3)	0.5 in.	4 in.
Sidewall Inside Face(AS4)	0.5 in.	4 in.

The diameters are used to estimate depth to tension reinforcing from compression face. They do not represent required reinforcing diameters.

SOIL LOAD DATA

Soil Density	120 pcf
Minimum Lateral Pressure Coefficient	0.25
Maximum Lateral Pressure Coefficient	0.50
Installation Type	Embankment/Compacted
Soil-Structure Interaction Factor	1.000

LIVE LOAD DATA: AASHTO - LRFD HL-93 Loading

Live Load: 1

Live Load Type	HS-Series
Live Load Magnitude	20 tons
Footprint specification	by Code
Tire Footprint Length	10 in.
Tire Footprint Width	20 in.

```
    Live Load Distribution Factor                          1.15
    Direction of Travel                    Parallel to Span
    Impact Factor                               Design Code
    Lane Load                                      0 lb/ft

Live Load: 2
    Live Load Type                      Interstate - Tandem
    Live Load Magnitude                            25 kips
    Footprint specification                        by Code
    Tire Footprint Length                           10 in.
    Tire Footprint Width                            20 in.
    Live Load Distribution Factor                     1.15
    Direction of Travel                    Parallel to Span
    Impact Factor                               Design Code
    Lane Load                                      0 lb/ft

--------------------------------------------------------------------------------
SURCHARGE LOADS
  Vertical Pressure                                0.0 lb/sq. ft
  Horiz. Pressure at Culvert Top                   0.0 lb/sq. ft
  Horiz. Pressure at Culvert Bottom                0.0 lb/sq. ft
  Application Code                  Additional Dead Load
--------------------------------------------------------------------------------
FLUID LOADS
  Depth of Fluid                                   10.0 ft
  Fluid Density                                    62.5 pcf
--------------------------------------------------------------------------------
LOAD COMBINATIONS
--------------------------------------------------------------------------------
Load Factors:Std
     Self Weight    V. Earth       L. Earth       Water          Live
Max   1.25           1.30           1.35           1.00           1.75
Min   0.90           0.90           0.90           0.00           0.00

Load Modifiers:
     Self Weight    V. Earth       L. Earth       Water          Live
      1.00           1.05           1.05           1.00           1.00

Load Factor for Axial Thrust:
1.00

Number of Load Combinations:
 4

Load Combinations: Std
Purpose      Self W Earth  Lat E. Fluid  V Live AppVeh Surch  V Sur  H Sur
MaxV/MaxH    Max    Max    Max    0.00   Max    Max    A      Max    Max
MaxV/MinH    Max    Max    Min    Max    Max    0.00   A      Max    0.00
MinV/MaxH    Min    Min    Max    0.00   0.00   Max    A      0.00   Max
Fatigue                                 0.00
--------------------------------------------------------------------------------
STRENGTH REDUCTION FACTORS
--------------------------------------------------------------------------------
  Flexure                                          1.00
  Shear                                            0.90
```

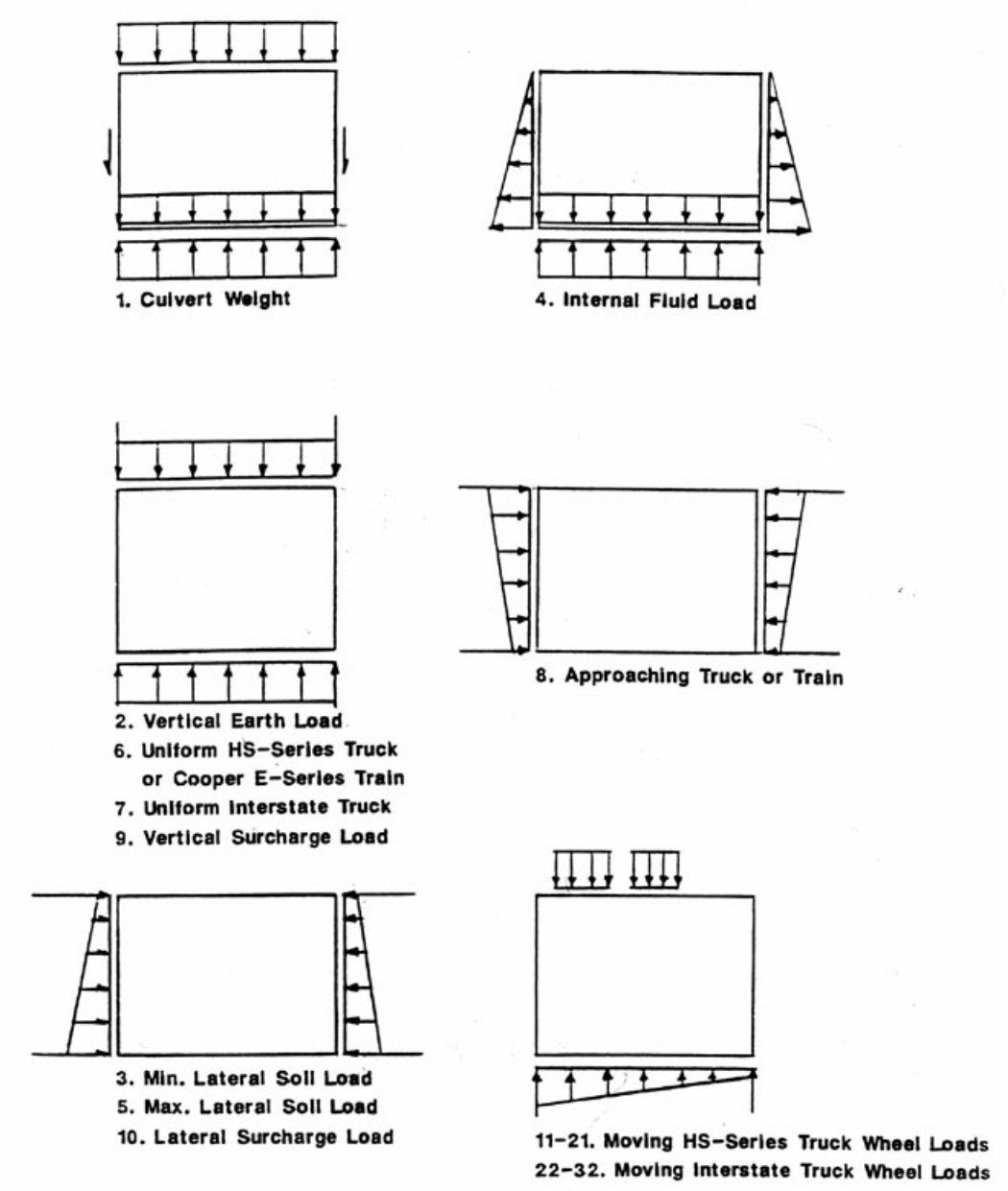
MEMBER LOADS
Load Conditions 1 to 10

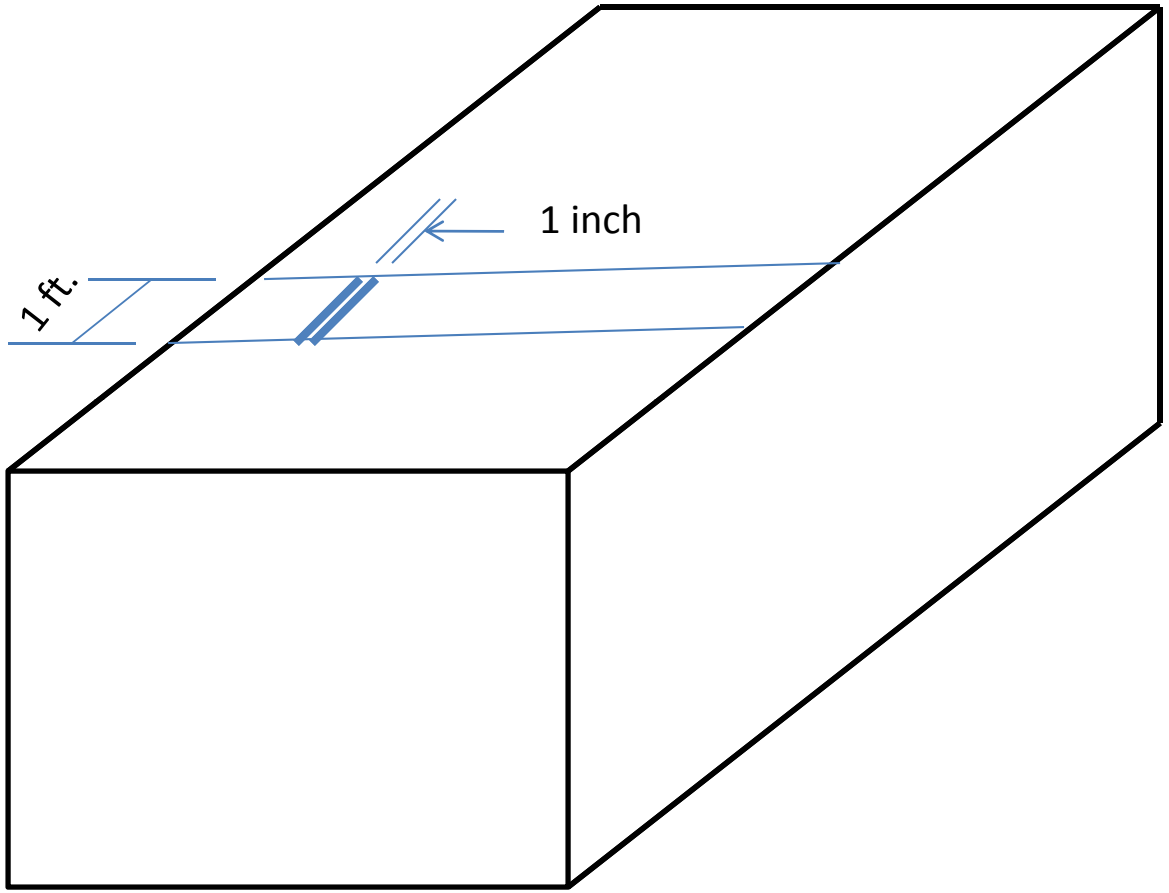
Load Condition	Member	Load Intensity at Start of Load (k/in./ft)	Load Intensity at End of Load (k/in./ft)	Distance from A-End to Start of Load (in.)	Distance from A-End to End of Load (in.)
1	1	0.010	0.010	0.0	130.0
1	2	0.000	0.000	0.0	0.0
1	3	0.033	0.033	0.0	130.0
1	4	0.000	0.000	0.0	0.0
2	1	0.000	0.000	0.0	130.0
2	2	0.000	0.000	0.0	0.0
2	3	0.000	0.000	0.0	130.0
2	4	0.000	0.000	0.0	0.0
3	1	0.000	0.000	0.0	0.0
3	2	0.000	0.029	0.0	130.0
3	3	0.000	0.000	0.0	0.0
3	4	0.029	0.000	0.0	130.0
4	1	0.000	0.000	0.0	0.0
4	2	0.000	-0.052	5.0	125.0
4	3	-0.004	-0.004	5.0	125.0
4	4	-0.052	0.000	5.0	125.0
5	1	0.000	0.000	0.0	0.0
5	2	0.000	0.029	0.0	130.0
5	3	0.000	0.000	0.0	0.0
5	4	0.029	0.000	0.0	130.0
6	1	0.000	0.000	0.0	0.0
6	2	0.000	0.000	0.0	0.0
6	3	0.000	0.000	0.0	0.0
6	4	0.000	0.000	0.0	0.0
7	1	0.000	0.000	0.0	130.0
7	2	0.000	0.000	0.0	0.0
7	3	0.000	0.000	0.0	130.0
7	4	0.000	0.000	0.0	0.0
8	1	0.000	0.000	0.0	0.0
8	2	0.013	0.009	0.0	130.0
8	3	0.000	0.000	0.0	0.0
8	4	0.009	0.013	0.0	130.0
9	1	0.000	0.000	0.0	130.0
9	2	0.000	0.000	0.0	0.0
9	3	0.000	0.000	0.0	130.0
9	4	0.000	0.000	0.0	0.0
10	1	0.000	0.000	0.0	0.0
10	2	0.000	0.000	0.0	130.0
10	3	0.000	0.000	0.0	0.0
10	4	0.000	0.000	0.0	130.0

Loading Conditions Figure

Load pressure distributions are shown here for each of the load cases in BOXCAR.

See Loading Conditions Table and index for additional information.





Load Case 1, Member 1 – [(10” x 12” x 1”)/1728] x (150 pcf/1000) = 0.0104 k/in./ft.

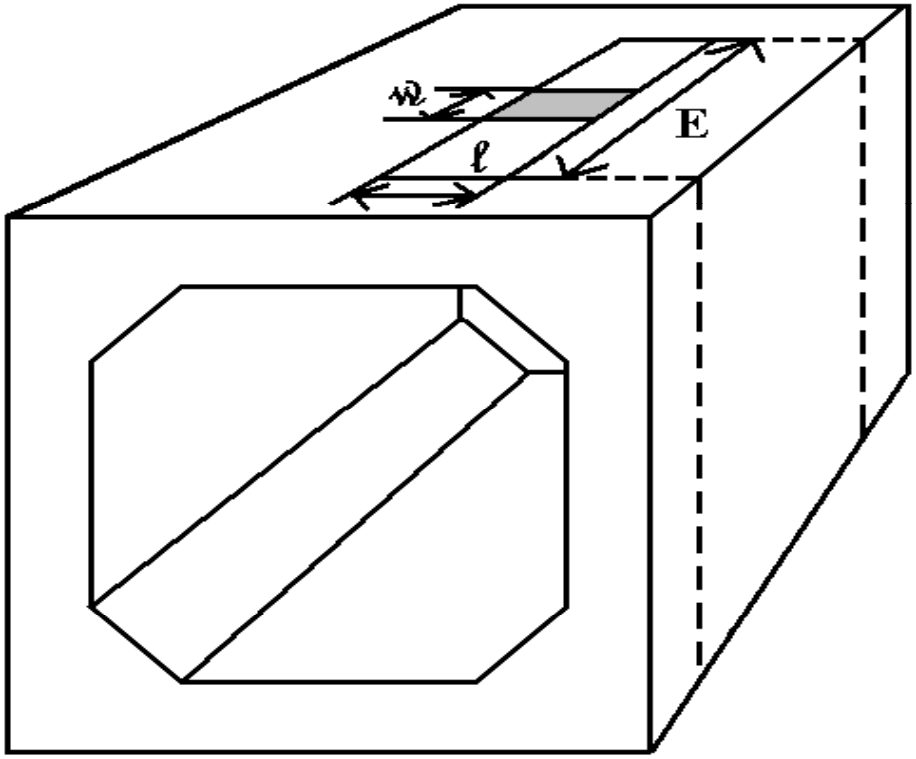
****** MEMBER LOADS ******

Truck Number 1: AASHTO HS-20
Truck Number 2: AASHTO Interstate Tandem

TRUCK WHEEL LOADS ACTING ON CULVERT TOP SLAB
(Includes Impact Factor: 1.33 and multiple presence factor: 1.2)

Load Case Number	Truck Position Number	Truck Number	Load Number	Load Intensity kip/in/ft	Distance from A-End To Start Of Load in.	Distance from A-End To End of Load in.
11	1	1	1	0.000	0.00	0.00
11	1	1	2	0.555	0.00	5.00
11	1	1	3	0.000	0.00	0.00
12	2	1	1	0.000	0.00	0.00
12	2	1	2	0.555	7.75	17.75
12	2	1	3	0.000	0.00	0.00
13	3	1	1	0.000	0.00	0.00
13	3	1	2	0.555	17.75	27.75
13	3	1	3	0.000	0.00	0.00
14	4	1	1	0.000	0.00	0.00
14	4	1	2	0.555	33.88	43.88
14	4	1	3	0.000	0.00	0.00
15	5	1	1	0.000	0.00	0.00
15	5	1	2	0.555	46.94	56.94
15	5	1	3	0.000	0.00	0.00
16	6	1	1	0.000	0.00	0.00
16	6	1	2	0.555	60.00	70.00
16	6	1	3	0.000	0.00	0.00
17	7	1	1	0.000	0.00	0.00
17	7	1	2	0.555	73.06	83.06
17	7	1	3	0.000	0.00	0.00
18	8	1	1	0.000	0.00	0.00
18	8	1	2	0.555	86.13	96.13
18	8	1	3	0.000	0.00	0.00
19	9	1	1	0.000	0.00	0.00
19	9	1	2	0.555	102.25	112.25
19	9	1	3	0.000	0.00	0.00
20	10	1	1	0.000	0.00	0.00
20	10	1	2	0.555	112.25	122.25
20	10	1	3	0.000	0.00	0.00
21	11	1	1	0.000	0.00	0.00
21	11	1	2	0.555	125.00	130.00
21	11	1	3	0.000	0.00	0.00
22	1	2	1	0.000	0.00	0.00
22	1	2	2	0.434	0.00	5.00
22	1	2	3	0.000	0.00	0.00
23	2	2	1	0.000	0.00	0.00
23	2	2	2	0.434	7.75	17.75
23	2	2	3	0.000	0.00	0.00
24	3	2	1	0.000	0.00	0.00
24	3	2	2	0.434	17.75	27.75
24	3	2	3	0.000	0.00	0.00

Box Under Shallow Fill Distribution Width



E = 96 +1.44 (s) ;
E in inches, s in feet

Live Load Intensity

Live Load Dist = [96 + 1.44 (10)]/12 = 9.2 ft.

Live Load = (P x DLA x MPF)/(Tire Length x Distribution Width)

Single Axle

Live Load = (32 kips x 1.33 x 1.2)/(10 in x 9.2 ft) = 0.555 kip/in/ft

Double Axle

Live Load = (25 kips x 1.33 x 1.2)/(10 in x 9.2 ft) = 0.434 kip/in/ft

25	4	2	1	0.000	0.00	0.00
25	4	2	2	0.434	33.88	43.88
25	4	2	3	0.000	0.00	0.00
26	5	2	1	0.000	0.00	0.00
26	5	2	2	0.434	46.94	56.94
26	5	2	3	0.434	0.00	8.94
27	6	2	1	0.000	0.00	0.00
27	6	2	2	0.434	60.00	70.00
27	6	2	3	0.434	12.00	22.00
28	7	2	1	0.000	0.00	0.00
28	7	2	2	0.434	73.06	83.06
28	7	2	3	0.434	25.06	35.06
29	8	2	1	0.000	0.00	0.00
29	8	2	2	0.434	86.13	96.13
29	8	2	3	0.434	38.13	48.13
30	9	2	1	0.000	0.00	0.00
30	9	2	2	0.434	102.25	112.25
30	9	2	3	0.434	54.25	64.25
31	10	2	1	0.000	0.00	0.00
31	10	2	2	0.434	112.25	122.25
31	10	2	3	0.434	64.25	74.25
32	11	2	1	0.000	0.00	0.00
32	11	2	2	0.434	125.00	130.00
32	11	2	3	0.434	77.00	87.00

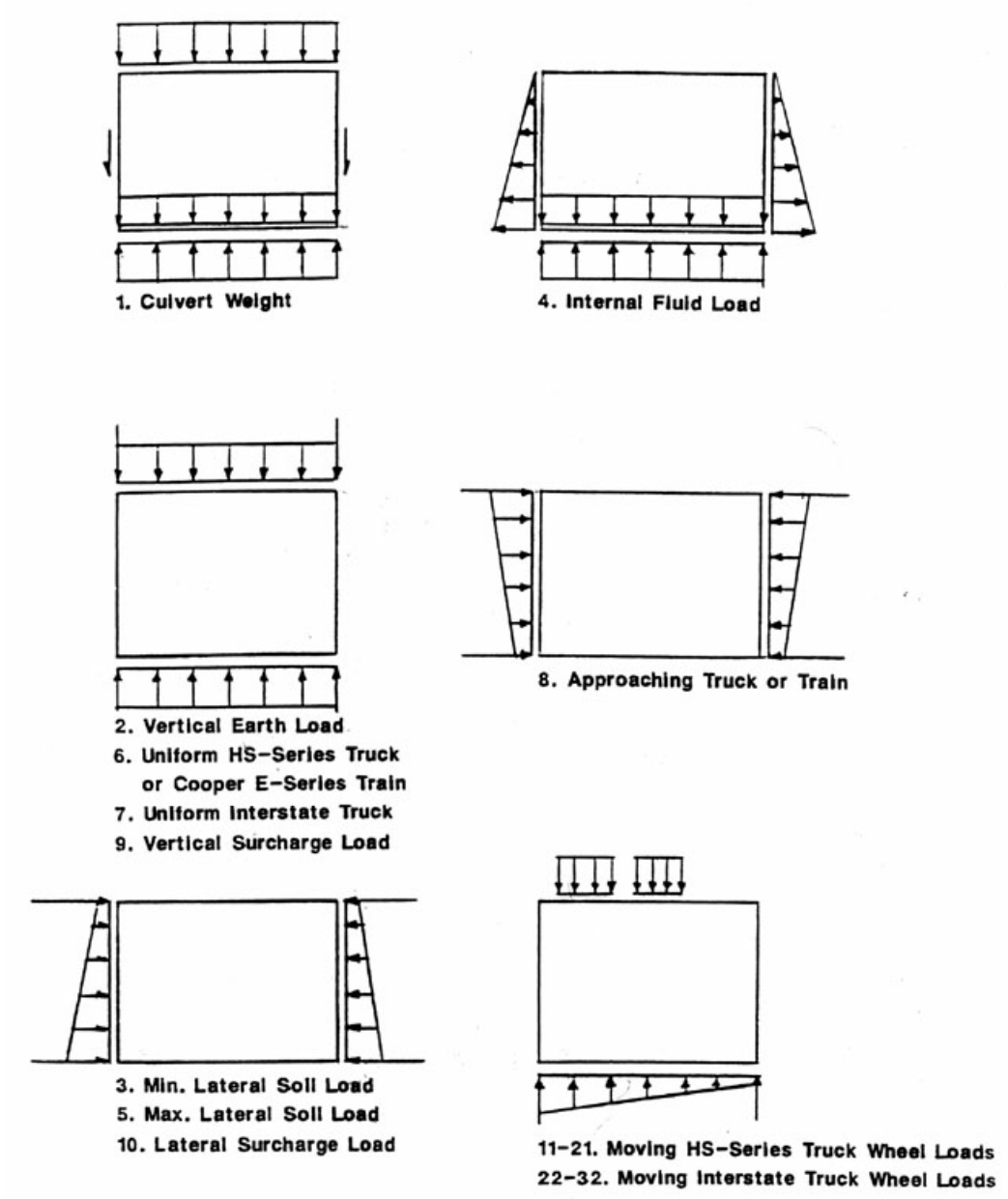
TRUCK WHEEL LOADS ACTING ON CULVERT BOTTOM SLAB

Load Case Number	Truck Position Number	Truck Number	---Load Intensity--- at start	at end	Distance from A-End To Start Of Load	To End of Load
			kip/in/ft	kip/in/ft	in.	in.
11	1	1	0.000	0.740	122.50	130.00
12	2	1	0.000	0.290	91.75	130.00
13	3	1	0.000	0.163	61.75	130.00
14	4	1	0.000	0.095	13.38	130.00
15	5	1	0.017	0.068	0.00	130.00
16	6	1	0.043	0.043	0.00	130.00
17	7	1	0.068	0.017	0.00	130.00
18	8	1	0.095	0.000	0.00	116.62
19	9	1	0.163	0.000	0.00	68.25
20	10	1	0.290	0.000	0.00	38.25
21	11	1	0.740	0.000	0.00	7.50
22	1	2	0.000	0.578	122.50	130.00
23	2	2	0.000	0.227	91.75	130.00
24	3	2	0.000	0.127	61.75	130.00
25	4	2	0.000	0.074	13.38	130.00
26	5	2	0.000	0.185	41.40	130.00
27	6	2	0.000	0.141	7.00	130.00
28	7	2	0.033	0.100	0.00	130.00
29	8	2	0.073	0.060	0.00	130.00
30	9	2	0.123	0.011	0.00	130.00
31	10	2	0.157	0.000	0.00	110.25
32	11	2	0.132	0.000	0.00	98.50

Loading Conditions Figure

Load pressure distributions are shown here for each of the load cases in BOXCAR.

See Loading Conditions Table and index for additional information.



****** SUMMARY OF SHEAR ANALYSES OF SECTIONS ******

Section (1)	Controlling Load Combin. (2)	Ultimate Shear Vu (kip/ft)	Allowable Shear Phi*Vc (kip/ft)	Diagonal Tension Index	Eff. Shear Depth (in.)	Required Shear Steel (3) (in.²/ft/line)
13 (t)	2-pos	9.5	12.4	0.77	8.48	0.000
12 (t)	2-pos	9.5	12.4	0.77	8.48	0.000
45 (t)	1-neg	-8.4	11.6	0.72	7.60	0.000
44 (t)	1-neg	-8.4	11.6	0.72	7.60	0.000
14 (s)	1-neg	-2.5	13.4	0.19	8.60	0.000
15 (s)	1-neg	-2.5	13.4	0.19	8.60	0.000
16 (s)	1-neg	2.5	14.7	0.17	8.60	0.000
17 (s)	1-neg	2.5	14.7	0.17	8.60	0.000
18 (b)	1-neg	-6.9	13.7	0.51	8.60	0.000
19 (b)	1-neg	-6.9	13.7	0.51	8.60	0.000
97 (b)	2-pos	6.8	13.5	0.50	8.50	0.000
96 (b)	2-pos	6.8	13.5	0.50	8.50	0.000

Notes

1. (t) top slab, (b) bottom slab, (s) side wall

2. Load combination that controls shear steel requirements. Other load combinations may control stirrup spacing and increased flexural steel requirements per AASHTO LRFD section 5.8.3.5

3. Required shear steel area based on user specified stirrup spacing. If the user defined stirrup spacing is too large, based on an examination of the entire slab, the shear steel area will change from the value shown in this table. See SHEAR DESIGN TABLE on the next page for shear steel design.

****** SHEAR DESIGN TABLE ******

Member	Top Slab	Sidewall	Bottom Slab
Section Controlling Stirrup Design	12	71	19
Load Combo Controlling Stirrup Design	2-pos	1-neg	1-neg
Vu*D/Mu (1)	0.642	0.191	1.505
Ultimate Shear (kip/ft)	9.50	-2.50	-6.94
Ultimate Thrust (kip/ft)	-0.58	6.52	3.81
Reinf. Ratio	0.0041	0.0023	0.0023
Eff. Shear Depth (in.)	8.48	8.60	8.60
Distance to A-END, (in.)	22.75	106.25	106.25
Diagonal Tension Phi * Vc (kip/ft)	12.39	13.38	13.75
Ultimate Shear/ Conc.Strength, Phi*Vc	0.77	0.19	0.51
Shear Steel Area (in^2/ft/line)	---	---	---
Stirrup Spacing (in.)	---	---	---
Number of Lines of Stirrups from A-end	---	---	---
Stirrups Start at	---	---	---
Number of Lines of Stirrups from B-end	---	---	---
Stirrups Start at	---	---	---
Flex. Steel Provisions Per AASHTO LRFD Section5.8.3.5	provisions satisfied / not applic.	provisions satisfied / not applic.	provisions satisfied / not applic.

******* FLEXURE DESIGN TABLE *******

rebar/ wall / face	Depth to Reinf in.	Ultimate Moment kip-in /ft	Ultimate Thrust kip/ft	Flex. Reinf. in²/ft	Max Reinf Area in²/ft	Crack Index	Governing Reinf Area in²/ft	Governing Mode	Governing section #	Governing section pos	Governing load combo
(1)				(2)	(3)	(4)	(5)	(6)		(7)	(8)
AS1,s,o	8.8	-149.4	6.52	0.213	2.252	0.56	0.240	Min Stl	57	60.1	2
AS2,t,i	8.8	235.4	-0.40	0.431	2.314	0.63	0.431	Flexure	1	65.0	2
AS3,b,i	8.8	215.7	-0.66	0.396	2.294	0.65	0.396	Flexure	11	65.0	2
AS4,s,i	8.8	64.3	1.41	0.102	2.258	0.24	0.240	Min Stl	58	63.4	3
AS7,t,o	7.8	-29.2	1.85	0.040	2.050	0.06	0.240	Min Stl	32	66.7	3
AS8,b,o	8.8	--	-0.66	0.000	2.294	0.00	0.240	Min Stl	84	63.4	2

Notes:
1. t-top slab, b-bottom slab, s-sidewall; i-inside face; o-outside face
2. Required reinforcing to develop ultimate flexural strength.
3. Maximum allowable flexural reinforcement area per compression provisions.
4. Crack Index is defined as the total service load stress divided by the allowable total service load stress.
5. Reinforcing required to meet all design criteria. The governing criteria is indicated under the column 'Governing Mode'. If 'REDES' the culvert must be redesigned because the required steel amount exceeds the allowable amount as dictated by compression provisions.
6. Governing modes:
   - Flexure - governed by provisions for flexure and axial force.
   - Min Stl - governed by provisions for minimum steel.
   - Crack - governed by provisions for cracking. The reinforcing may be reduced by decreasing the maximum reinforcing spacing.
   - Compres - the culvert must be redesigned because the required steel amount exceeds the allowable amount as dictated by compression provisions. Try increasing the depth of the slab or decreasing loads.
   - Fatigue - governed by provisions for fatigue
7. Location of section, measured with respect to End A (center) line dimensions of culvert).
8. Pos/Neg indicates truck positioned to produce maximum positive/negative moment.
9. Minimum flexural reinforcing computed as 0.002 times the gross concrete section.

Sidewall outside face steel (AS1) must be bent at the corner and extended:

top slab: 0 inches* + tension lap splice length
bottom slab: 0 inches* + tension lap splice length

*measured from the bend point

BOX CULVERT DESIGN SUMMARY SHEET
10.00 ft Span x 10.00 ft Rise

****

INSTALLATION DATA

Height of Fill Over Culvert, ft	0.00
Soil Unit Weight, pcf	120.
Minimum Lateral Soil Pressure Coefficient	0.250
Maximum Lateral Soil Pressure Coefficient	0.500
Soil-Structure Interaction Factor	1.000
Installation Type	Embankment/Compacted

MATERIAL PROPERTIES

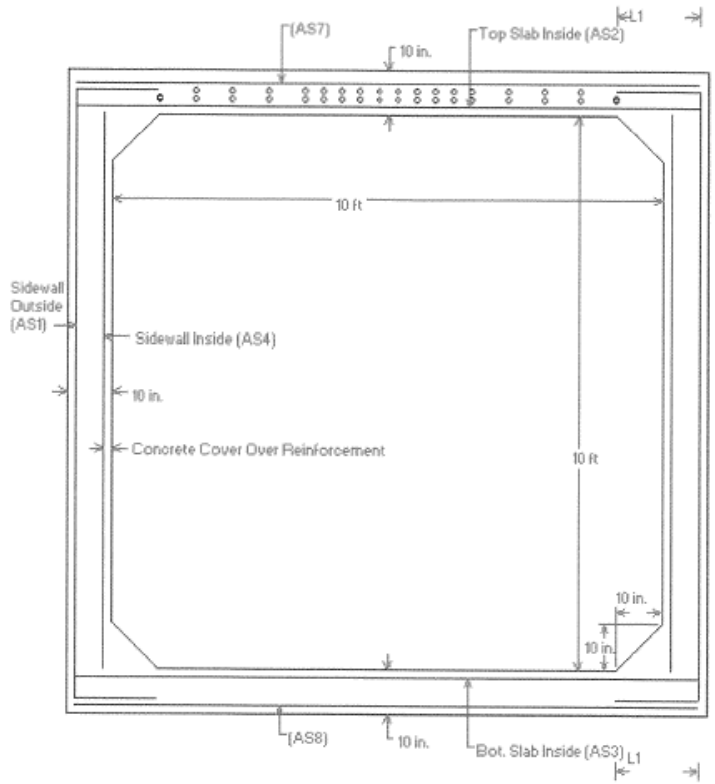
Minimum Specified Reinforcing Yield Strength, ksi	65.00
Concrete - Specified Compressive Strength, ksi	5.00

GEOMETRY

Top Slab Thickness, in.	10.0
Side Wall Thickness, in.	10.0
Bottom Slab Thickness, in.	10.0
Top Horizontal Haunch Dimension, in.	10.0
Bottom Horizontal Haunch Dimension, in.	10.0
Top Vertical Haunch Dimension, in.	10.0
Bottom Vertical Haunch Dimension, in.	10.0
Concrete Cover Over Steel, in.	
Top Slab - Outside Face	2.00
Bottom Slab - Outside Face	1.00
Side Wall - Outside Face	1.00
Top Slab - Inside Face	1.00
Bottom Slab - Inside Face	1.00
Side Wall - Inside Face	1.00

REINFORCING DATA

LOCATION	AREA (in.²/ft)	STIRRUPS REQUIRED?
TRANSVERSE		
Side Wall - Outside Face(AS1)	0.240	No
Top Slab - Inside Face(AS2)	0.431	No
Bottom Slab - Inside Face(AS3)	0.396	No
Side Wall - Inside Face(AS4)	0.240	No
Top Slab - Outside Face(AS7)	0.240	No
Bottom Slab - Outside Face(AS8)	0.240	No
DISTRIBUTION		
Top Slab - Inside Face(AS5)	0.24	
Top Slab - Outside Face(AS6)	0.24	



* <L1> is Splice Length
* (AS7) is Top Slab Outside
* (AS8) is Bottom Slab Outside
* Dots represent top (AS6) and bottom (AS5) distribution reinforcement.
* See Box Culvert Design Summary Sheet for transverse and distribution reinforcement, as required.
* For sidewall thicknesses of 6 in. and above, extend AS2 and AS3 a min. of 4 in. beyond the inside face of the sidewall. For thicknesses less than 6 in., extend AS2 and AS3 at least to within 1-1/2 in. of the outside face of the sidewall.

Notes:

1) Other reinforcement schemes that provide the required reinforcement areas at all locations identified in the program output are acceptable.
2) Only longitudinal reinforcement for top slab distribution is shown for clarity, see AASHTO M273 for additional longitudinal reinforcement and for additional requirements.

BOXCAR 3.0 DETAILED OUTPUT

Filename: Pipe School.csv

Date / Time: 11/10/2010 8:33:25 AM

This file is best read by opening in a spread sheet

LOAD FACTORS (moment & shear)

rows-> load combinations and cols-> load case #

internal load combo #	user defined combo #	load combo type	Self Weight	Minimum Vertical Earth	Minimum Lateral Earth	Internal Fluid	Additional Lateral Earth Pressure	Vertical Live-Positive Moment	Vertical Live-Negative Moment	Approaching Vehicle	Vertical Surcharge	Horizontal Surcharge	Lane Load
1	1-pos	strength	1.25	1.36	1.42	0	1.42	1.75	0	1.75	1.36	1.42	1.75
2	1-neg	strength	1.25	1.36	1.42	0	1.42	0	1.75	1.75	1.36	1.42	1.75
3	2-pos	strength	1.25	1.36	0.86	1	0	1.75	0	0	1.36	0	1.75
4	2-neg	strength	1.25	1.36	0.86	1	0	0	1.75	0	1.36	0	1.75
5	3-pos	strength	0.9	0.86	1.42	0	1.42	0	0	1.75	0	1.42	0
6	3-neg	strength	0.9	0.86	1.42	0	1.42	0	0	1.75	0	1.42	0
7	1-pos	service	1	1	1	0	1	1	0	1	1	1	1
8	1-neg	service	1	1	1	0	1	0	1	1	1	1	1
9	2-pos	service	1	1	1	1	0	1	0	0	1	0	1
10	2-neg	service	1	1	1	1	0	0	1	0	1	0	1
11	3-pos	service	1	1	1	0	1	0	0	1	0	1	0
12	3-neg	service	1	1	1	0	1	0	0	1	0	1	0
13	fatigue	fatigue	0	0	0	0	0	0	0	0	0	0	0
14	fatigue	fatigue	0	0	0	0	0	0	0	0	0	0	0

MOMENTS FOR EACH SECTION & LOAD CASE (kip-in/ft)

rows-> section # and cols-> load case #

Member	Section Pos(in.)	1	2	3	4	5	6	7	8	9	10
1 Top	65	19.1544	0	-10.6886	17.8159	-10.6886	0	0	-9.2194	0	0
2 Top	15	6.1336	0	-10.6886	17.8159	-10.6886	0	0	-9.2194	0	0
3 Top	5	0.4044	0	-10.6886	17.8159	-10.6886	0	0	-9.2194	0	0
4 Side	125	-3.9718	0	-7.6147	12.7607	-7.6147	0	0	-5.5001	0	0
5 Side	115	-6.2136	0	-1.5792	2.7225	-1.5792	0	0	0.9632	0	0
6 Side	65	-17.4228	0	19.063	-32.2772	19.063	0	0	14.7384	0	0
7 Side	15	-28.632	0	3.2469	-2.1727	3.2469	0	0	0.3262	0	0
8 Side	5	-30.8739	0	-6.7592	16.435	-6.7592	0	0	-5.613	0	0
9 Bottom	125	-21.7284	0	-12.8	25.8028	-12.8	0	0	-8.9406	0	0
10 Bottom	115	-3.6595	0	-12.8	23.5993	-12.8	0	0	-8.9406	0	0
11 Bottom	65	37.4062	0	-12.8	18.5913	-12.8	0	0	-8.9406	0	0
12 Top	22.75	9.8572	0	-10.6886	17.8159	-10.6886	0	0	-9.2194	0	0
13 Top	22.75	9.8572	0	-10.6886	17.8159	-10.6886	0	0	-9.2194	0	0
14 Side	106.25	-8.1752	0	3.4334	-5.7196	3.4334	0	0	5.5712	0	0
15 Side	106.25	-8.1752	0	3.4334	-5.7196	3.4334	0	0	5.5712	0	0
16 Side	23.75	-26.6704	0	9.8781	-14.5232	9.8781	0	0	4.7205	0	0
17 Side	23.75	-26.6704	0	9.8781	-14.5232	9.8781	0	0	4.7205	0	0
18 Bottom	106.25	9.4559	0	-12.8	21.9999	-12.8	0	0	-8.9406	0	0
19 Bottom	106.25	9.4559	0	-12.8	21.9999	-12.8	0	0	-8.9406	0	0

SHEAR FOR EACH SECTION & LOAD CASE (kip/ft)

rows-> section # and cols-> load case #

Member	Section Pos(in.)		1	2	3	4	5	6	7	8	9	10
1	Top	65	0	0	0	0	0	0	0	0	0	0
2	Top	15	0.5208	0	0	0	0	0	0	0	0	0
3	Top	5	0.625	0	0	0	0	0	0	0	0	0
4	Side	125	0.2242	0	-0.6129	1.011	-0.6129	0	0	-0.7111	0	0
5	Side	115	0.2242	0	-0.5905	0.9893	-0.5905	0	0	-0.5821	0	0
6	Side	65	0.2242	0	-0.1417	0.2298	-0.1417	0	0	0.0187	0	0
7	Side	15	0.2242	0	0.8679	-1.6148	0.8679	0	0	0.5454	0	0
8	Side	5	0.2242	0	1.1371	-2.114	1.1371	0	0	0.6419	0	0
9	Bottom	125	-1.9712	0	0	0.2404	0	0	0	0	0	0
10	Bottom	115	-1.6426	0	0	0.2003	0	0	0	0	0	0
11	Bottom	65	0	0	0	0	0	0	0	0	0	0

AXIAL FORCE FOR EACH SECTION & LOAD CASE (kip/ft) note '+' is compression

rows-> section # and cols-> load case #

	Member	Section Pos(in.)	1	2	3	4	5	6	7	8	9	10
1	Top	65	-0.2242	0	0.6157	-1.011	0.6157	0	0	0.8427	0	0
2	Top	15	-0.2242	0	0.6157	-1.011	0.6157	0	0	0.8427	0	0
3	Top	5	-0.2242	0	0.6157	-1.011	0.6157	0	0	0.8427	0	0
4	Side	125	1.4063	0	0	0	0	0	0	0	0	0
5	Side	115	1.4063	0	0	0	0	0	0	0	0	0
6	Side	65	1.4063	0	0	0	0	0	0	0	0	0
7	Side	15	1.4063	0	0	0	0	0	0	0	0	0
8	Side	5	1.4063	0	0	0	0	0	0	0	0	0
9	Bottom	125	0.2242	0	1.426	-2.114	1.426	0	0	0.7358	0	0
10	Bottom	115	0.2242	0	1.426	-2.114	1.426	0	0	0.7358	0	0
11	Bottom	65	0.2242	0	1.426	-2.114	1.426	0	0	0.7358	0	0

DETAILED ANALYSIS RESULTS FOR EACH SECTION/ EACH LOAD COMBINATION

section number	member	internal load combo number	user defined load combo number	load combo type	section pos	M	N	V	d	h	rho	
					in.	kip-in/ft	kip/ft	kip/ft	in.	in.		
1	top	1	1-pos	strength	65	180.33	2.07	3.79	8.75	10	0	
1	top	2	1-neg	strength	65	-22.49	1.85	-3.79	7.75	10	0	
1	top	3	2-pos	strength	65	235.42	-0.4	3.79	8.75	10	0	
1	top	4	2-neg	strength	65	32.6	-0.62	-3.79	8.75	10	0	
1	top	5	3-pos	strength	65	-29.2	1.85	0	7.75	10	0	
1	top	6	3-neg	strength	65	-29.2	1.85	0	7.75	10	0	
1	top	7	1-pos	service	65	104.46	2.07	2.16	8.75	10	0	
1	top	8	1-neg	service	65	-11.44	1.85	-2.16	7.75	10	0	
1	top	9	2-pos	service	65	142.18	-0.4	2.16	8.75	10	0	
1	top	10	2-neg	service	65	26.28	-0.62	-2.16	8.75	10	0	
1	top	11	3-pos	service	65	-11.44	1.85	0	7.75	10	0	
1	top	12	3-neg	service	65	-11.44	1.85	0	7.75	10	0	
1	top	13	fatigue	fatigue	65	0	0	0	7.75	10	0	
1	top	14	fatigue	fatigue	65	0	0	0	7.75	10	0	

350	DETAILED									
351	section nu	AsComp	AsCrack	AsFatigue	AsFlex	AsMin	AsShear	fs	fsallow	V
352		in²/ft	in²/ft	in²/ft	in²/ft	in²/ft	in²/ft	kip/ft	ksi	k
353	1	2.314	-	-	0.307	0.24	-	-	-	
354	1	2.05	-	-	0.027	0.24	-	-	-	
355	1	2.343	-	-	0.431	0.24	-	-	-	
356	1	2.345	-	-	0.063	0.24	-	-	-	
357	1	2.05	-	-	0.04	0.24	-	-	-	
358	1	2.05	-	-	0.04	0.24	-	-	-	
359	1	-	0.187	-	-	0.24	-	12.18	65	
360	1	-	0.015	-	-	0.24	-	0.644	43.658	
361	1	-	0.271	-	-	0.24	-	17.635	65	
362	1	-	0.045	-	-	0.24	-	2.932	65	
363	1	-	0.015	-	-	0.24	-	0.644	43.658	
364	1	-	0.015	-	-	0.24	-	0.644	43.658	
365	1	-	-	0	-	0.24	-	-	-	
366	1	-	-	0	-	0.24	-	-	-	

		AsShear in²/ft	fs kip/ft	fsallow ksi	Vc kip/ft	AsDesign in²/ft	eff. shear depth in.	beta	VsReqd kip/ft	(Vu * d)/ Mu	Vu / (Phi* Vc)	AvReqd in²/ft/line	SMax in.
507	12	0	-	-	16.55	0.431	8.476	2.303	0	0	0.638	0	0
508	12	0	-	-	20.387	0.24	7.597	3.165	0	0	0.014	0	0
509	12	0	-	-	13.767	0.431	8.476	1.916	0	0	0.767	0	0
510	12	0	-	-	30.718	0.431	8.476	4.274	0	0	0.009	0	0
511	12	0	-	-	20.951	0.24	7.597	3.252	0	0	0.021	0	0
512	12	0	-	-	20.951	0.24	7.597	3.252	0	0	0.021	0	0

The End