Box Culvert Design (Basics)

- Josh Beakley
- Director of Technical Services
- American Concrete Pipe Association

Standards/Specifications for Box Culverts

- M 259 (C789 - Discontinued)
- M 273 (C 850 - Discontinued)
- C1433 (Standard)
- C1577 (LRFD)

ASTM Precast Box Culvert Standard

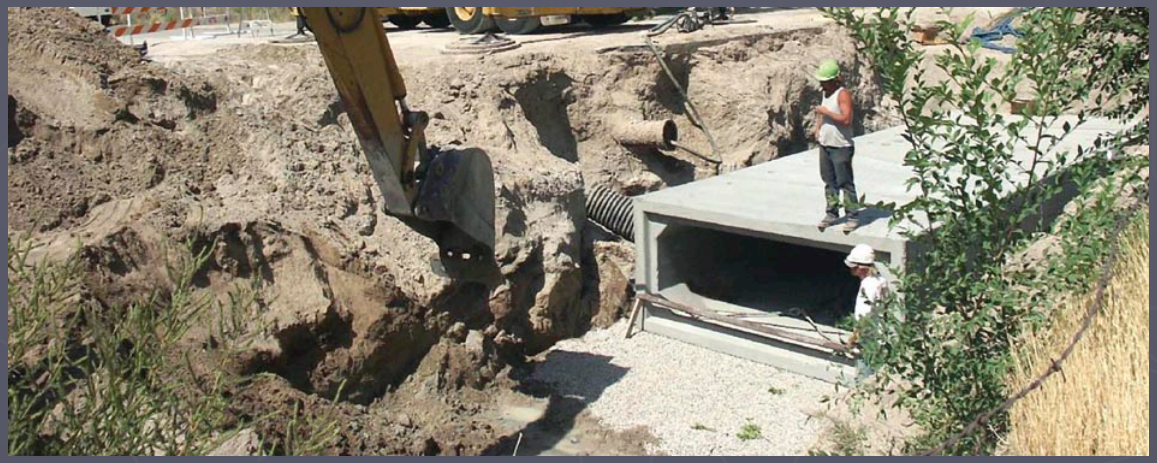
Designation: C1577 – 13a

Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers Designed According to AASHTO LRFD[1]

This standard is issued under the fixed designation C1577; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

Additional Box Culvert Sizes in C1577 - 13a

- 5 x 2
- 6 x 2
- 7 x 2, 7 x 3
- 8 x 2, 8 x 3
- 9 x 2, 9 x 3, 9 x 4
- 10 x 2, 10 x 3, 10 x 4
- 11 x 2, 11 x 3
- 12 x 2, 12 x 3



C 1577 Design Criteria

TABLE X1.1 Specific Criteria Used for Table 1[A]

Material Properties:	
Steel reinforcement, minimum specified yield stress	65 000 psi
Concrete, minimum specified compressive strength	5000 psi
Soil Data:	
Unit weight	120 lbf/ft^3
Ratio of lateral to vertical pressure from weight of earth	0.50 max to 0.25 min
External water table	below box section invert
Soil structure interaction factor	$F_s = 1 + 0.20(H/B_c)$ B_c = outside width of culvert $F_s$max = 1.15
Capacity Reduction Factors (from AASHTO LRFD Bridge Design Specifications):	
Shear	0.90
Axial compression combined with bending	1.0
Loading Data:	
Load Modifiers:	
Ductile Structures	$\eta = 1.0$
For earth fill: non-redundant member	$\eta = 1.05$
For live load: redundant member	$\eta = 1.0$
Typical Bridge	$\eta = 1.0$
Load Factors:	
Dead Load	Max DL = 1.25, Min DL = 0.90
Earth Load (Vertical)	Max ELV = 1.30, Min ELV = 0.90
Earth Load (Horizontal)	Max ELH = 1.35 (see X1.2.5)
Live Load	LL = 1.75
Multiple Presence Factor	MPF = 1.2 (for one lane)
Live Load HL-93:[B]	
Greater of:	
Truck Axle Load	32 000 lbf
Tandem Axle Load	2 at 25 000 lbf each
H < 2 ft	
Area of box section resisting truck axle load	
Direction Perpendicular to Span	E = 96 (in.) + 1.44Span (ft)
Direction Parallel to Span	L = 10 (in.) + 1.15H (in.)
H ≥ 2 ft	
Area of box section resisting truck wheel load	
Direction Perpendicular to Span	W = 20 (in.) + 1.15H (in.)
Direction Parallel to Span	L = 10 (in.) + 1.15H (in.)
Dynamic Load Allowance (variable with depth)	= 0.33(1 − 0.125H)
Uniform internal pressure	0.0
Depth of water in box section	equal to inside height
External ground water pressure	0.0
Lateral Live Load Pressure:	
From 0 to 5 ft	160 psf
5 ≥ 10 ft	160 − [(H-5)/(10-5)](160-120) psf
10 ≥ 20 ft	120 − [(H-10)/(20-10)](120-80) psf
20 ft or greater	80 psf
Structural Arrangement:	
Reinforcement Spacing	4.0 in.
Concrete cover over steel	1.0 in.
Top slab (outside face)	1.0 in. for fill heights 2 ft and greater, 2.0 in. for fill heights under 2 ft
Side wall thickness	1/12 times inside span plus 1.0 in. up to 7-ft span, 1/12 inside span above 7-ft span
Slab thickness	equal to sidewall thickness unless otherwise noted
Haunch dimensions	vertical and horizontal dimensions both equal to side wall thickness
Minimum reinforcing inside face slabs and side walls, outside face side walls and corners of slabs	0.002 bt

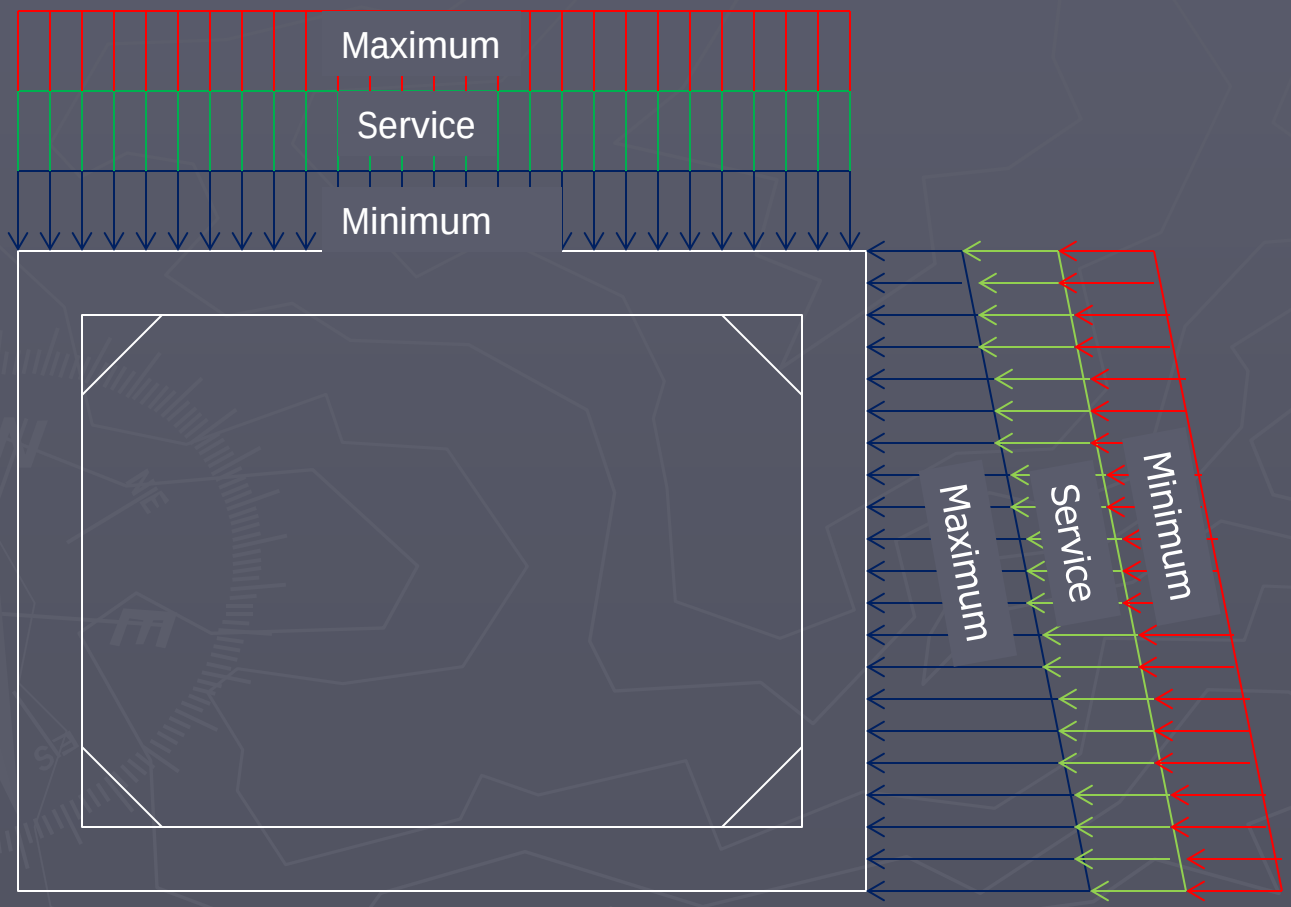
[A] The structural arrangement and details are shown in Fig. 1.
[B] Refer to Fig. X1.1 for wheel load arrangements.

AASHTO LRFD Bridge Design Specifications

- Section 3 – Loads and Load Factors
- Section 4 – Structural Analysis and Evaluation
- Section 5 – Concrete Structures
- Section 12 – Buried Structures and Tunnel Liners


03/03/2006

LRFD Design



AASHTO LRFD Bridge Design Specifications

C12.11.2.1

Add the following to the beginning of this Article:

For the design of box culverts, three general load combinations envelope all controlling force effects for the Strength and Service limit states. These are:

- Maximum vertical, Maximum horizontal
- Maximum vertical, Minimum horizontal
- Minimum vertical, Maximum horizontal

Controlling force effects with maximum horizontal loads may occur with live load surcharge (LS) present or absent. Both situations should be investigated.

Move the existing paragraph in this Article below the proposed added paragraph, since it relates to the first paragraph in Article 12.11.2.1.

HL-93 Live Load

- 3.6.1.2.1
  - "Vehicular live loading on the roadways of bridges or incidental structures, designated HL-93, shall consist of a combination of the:
    - Design truck or design tandem, and
    - Design lane load"

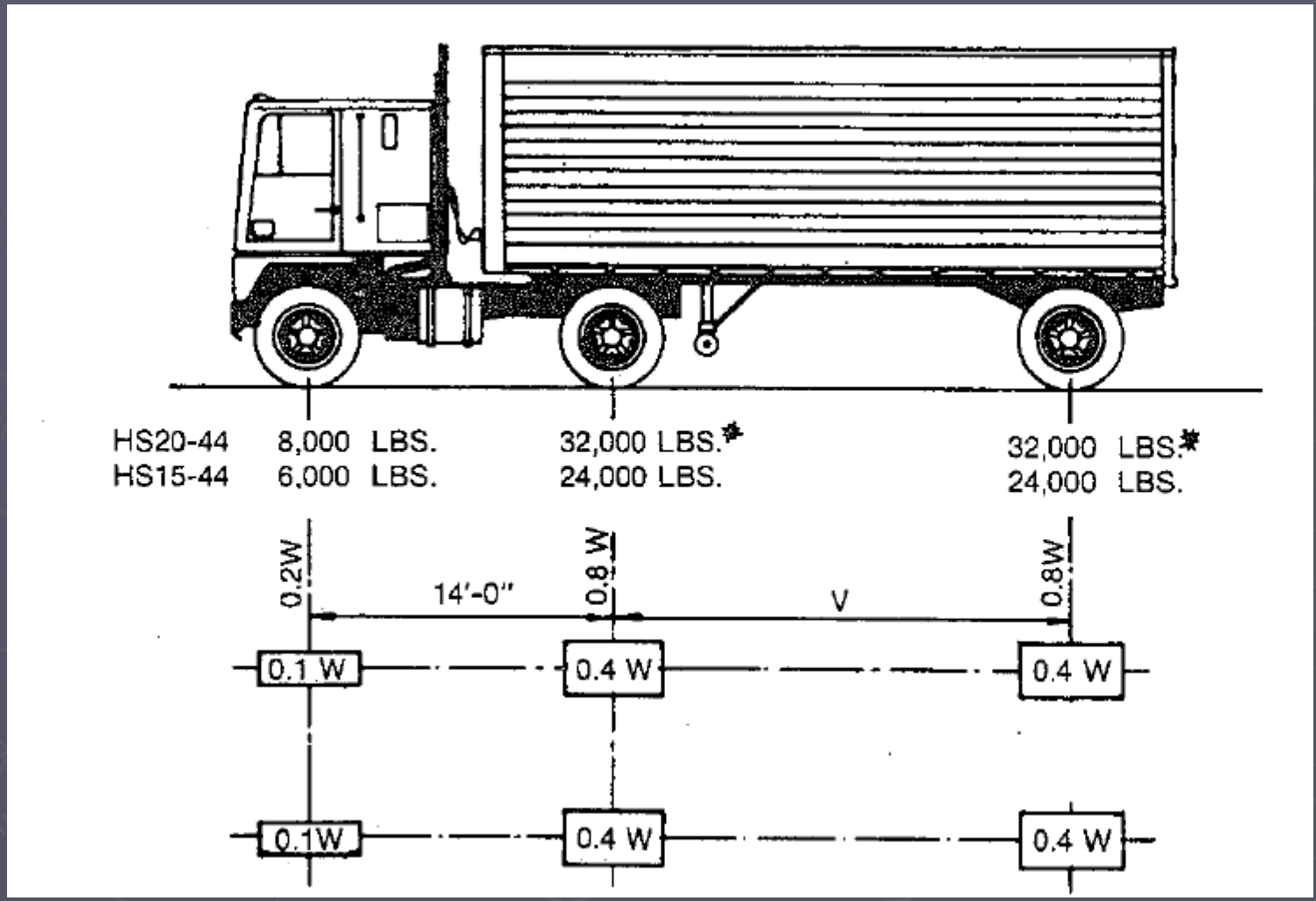
Applied Live loads

- 3.6.1.3.3 Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts
  - Where the slab spans primarily in the transverse direction, only the axles of the design truck of Article 3.6.1.2.2 or design tandem of Article 3.6.1.2.3 shall be applied to the deck slab of the top of box culverts.

Applied Live loads

- 3.6.1.3.3 Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts
  - Where the slab spans primarily in the longitudinal direction:
  - For top slabs of box culverts of all spans and for all other cases, including slab-type bridges where the span does not exceed 15.0 ft, only the axle loads of the design truck or design tandem of Articles 3.6.1.2.2 and 3.6.1.2.3, respectively, shall be applied.

HS20 or HL 93 Single Axle



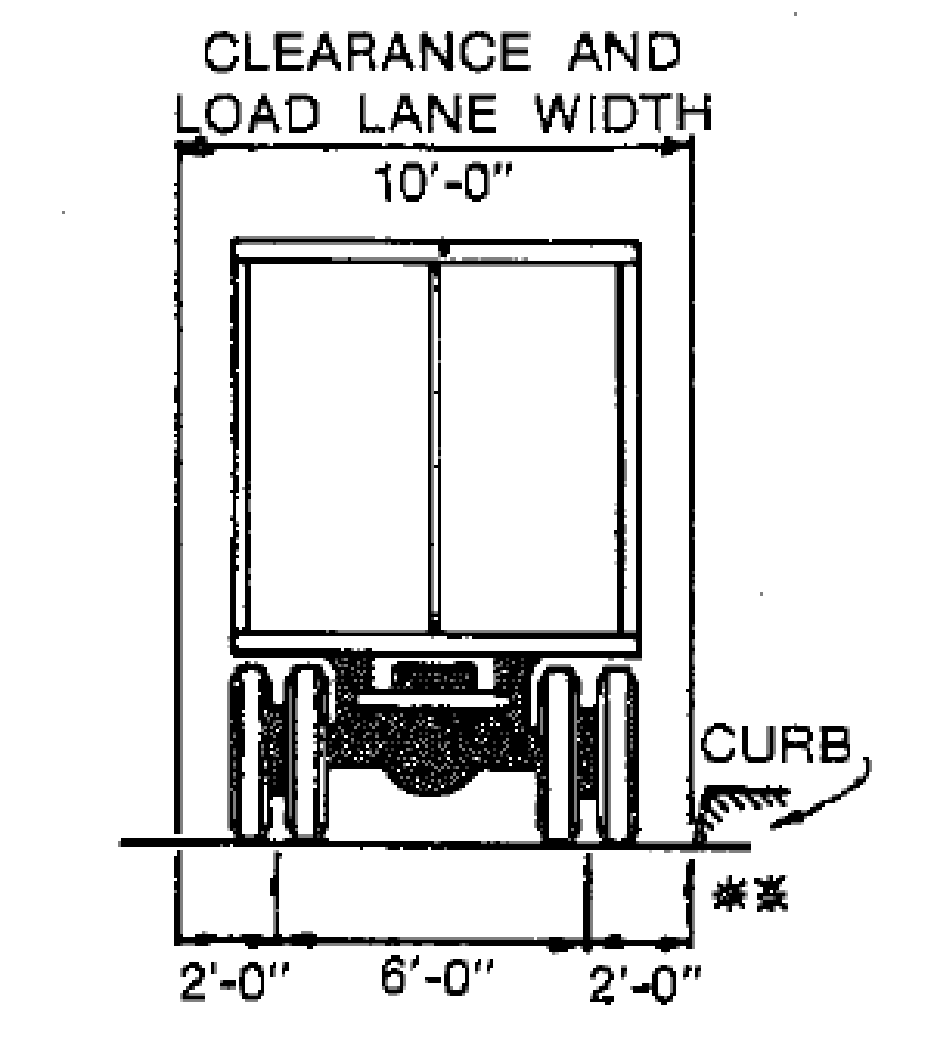
How Far Down?

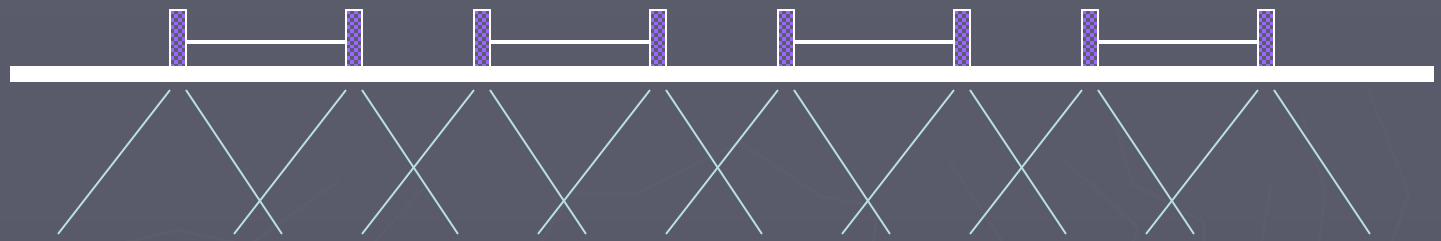
- 3.6.1.2.6
- “For single-span culverts, the effects of live load may be neglected where the depth of fill is more than 8.0 ft and exceeds the span length;”

Single Loaded Lane When Less Than 2 Feet

- 12.11.2.1 – “For traffic traveling parallel to the span, box culverts shall be designed for a single loaded lane with the single lane multiple presence factor.”

Axle Width





Multiple Presence Factor	
Lanes	MPF
1	1.2
2	1.0
3	0.85
4	0.65

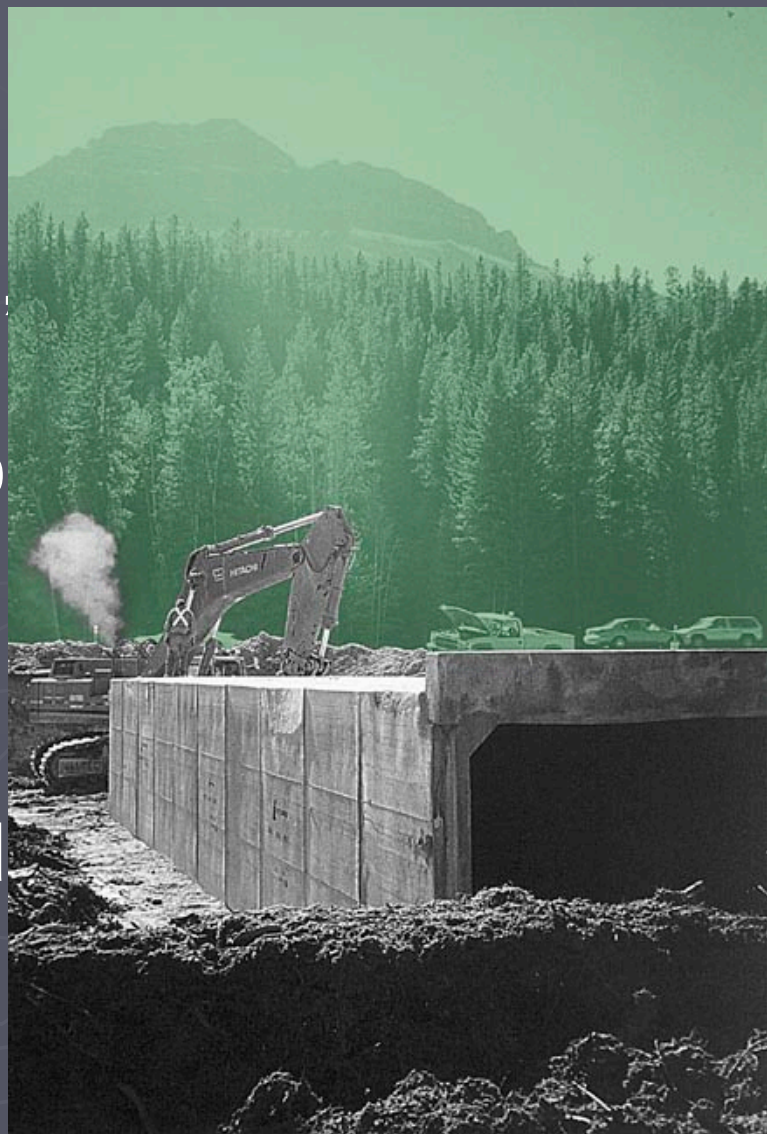
Shear Transfer

- *4.6.2.10.4 Precast Box Culverts*
- For precast box culverts with top slabs having span to thickness ratios (s/t) of 18 or less and segment lengths equal to or greater than 4 feet in length, shear transfer across the joint need not be provided.

Edge Beams

12.11.2.1

- For cast in place box culverts, and for precast box culverts with top slabs having span to thickness ratios (s/t) greater than 18 or segment lengths less than 4.0 ft., edge beams shall be provided as specified in Article 4.6.2.1.4



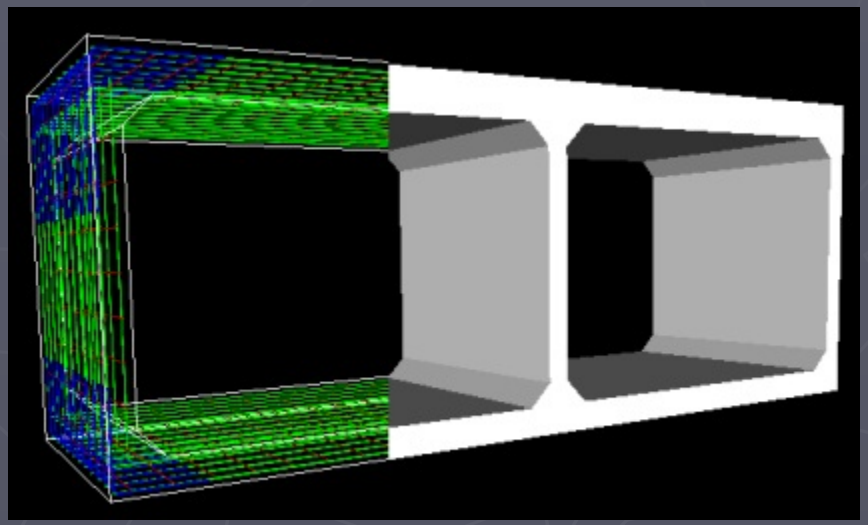
Fatigue

LRFD – 5.5.3.1

“Fatigue need not be investigated for concrete deck slabs in multigirder applications or reinforced-concrete box culverts.”

ETCulvert

Concrete Culvert Design in Accordance with AASHTO LRFD Specifications



ETCulvert Scope

- Handles both 3- and 4-sided culverts
- 1 to 4 cells
- Includes both US Customary and Metric (SI) Units
- Supports:
  - LRFD 5th Edition
  - STND 17th Edition
  - AREMA 2010 Edition

Text Report

Strength Limit State at Critical Sections: Flexure

Member 1: (Exterior Wall), Thickness = 6.00 in

Loc	Dist. (in)	Design Moment (k-ft)	Corr. A. F. (k)	Mu (k-ft)	Ma (k-ft)	phi	As (in2)	1.2Mcr (k-ft)	Load Ratings IR (Str I)	Load Ratings OR (Str II)
BOT	9.00	-2.32	11.89	3.61	5.20	0.90	0.14	5.96	2.83	3.67
MID	34.00	0.85	1.18	1.58	1.62	0.90	0.06	5.96	2.90	3.76
MID-	34.00	-1.98	11.75	3.61	5.17	0.90	0.14	5.96	2.58	3.34
TOP	9.00	-3.77	11.89	3.61	5.20	0.90	0.14	5.96	1.47	1.91

Member 2: (Top Slab), Thickness = 8.00 in

Loc	Dist. (in)	Design Moment (k-ft)	Corr. A. F. (k)	Mu (k-ft)	Ma (k-ft)	phi	As (in2)	1.2Mcr (k-ft)	Load Ratings IR (Str I)	Load Ratings OR (Str II)
LT	7.00	-1.96	2.08	4.37	4.41	0.90	0.14	10.59	2.62	3.40
MID	45.00	13.71	0.16	16.04	14.47	0.90	0.46	10.59	1.06	1.37
RT	7.00	-7.12	1.17	10.79	9.96	0.90	0.36	10.59	1.51	1.96

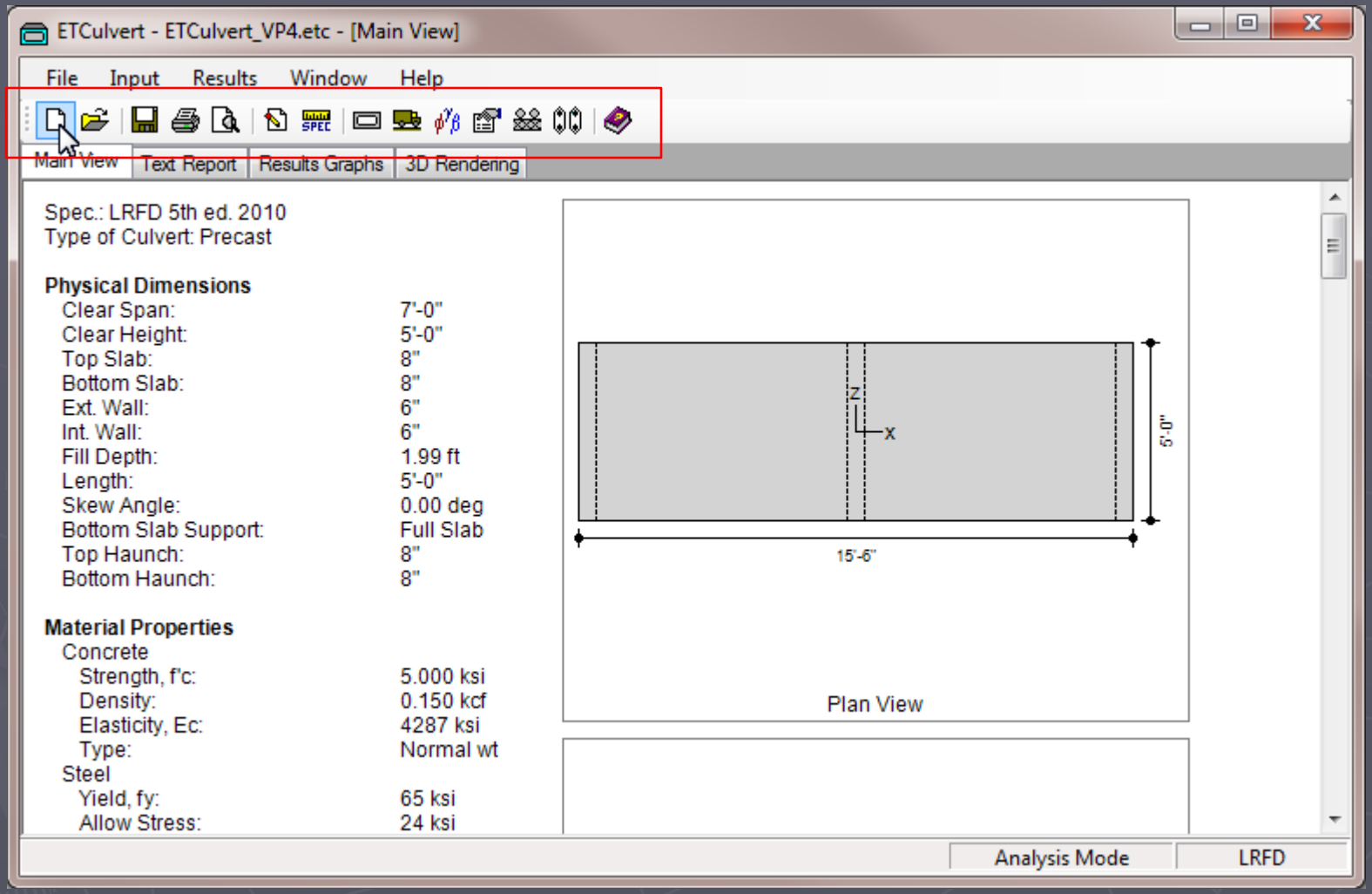
Member 3: (Interior Wall), Thickness = 6.00 in

Loc	Dist. (in)	Design Moment (k-ft)	Corr. A. F. (k)	Mu (k-ft)	Ma (k-ft)	phi	As (in2)	1.2Mcr (k-ft)	Load Ratings IR (Str I)	Load Ratings OR (Str II)
BOT	9.00	-1.38	16.59	3.13	5.54	0.90	0.12	5.96	6.19	8.02
MID	34.00	1.03	3.76	3.13	3.43	0.90	0.12	5.96	3.32	4.30
TOP	9.00	-2.95	16.87	3.13	5.59	0.90	0.12	5.96	1.89	2.45

Member 4: (Bottom Slab), Thickness = 8.00 in

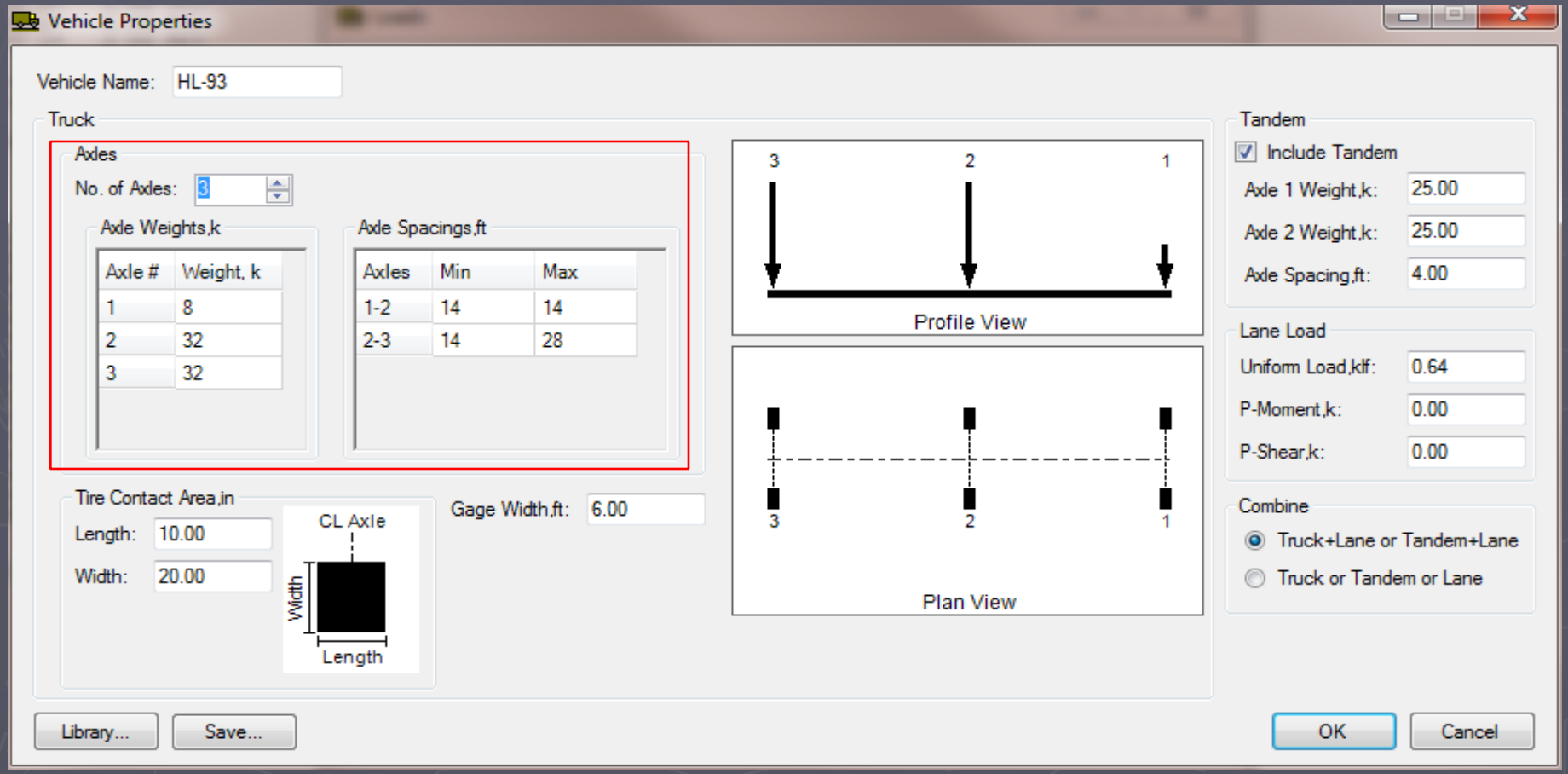
Loc	Dist. (in)	Design Moment (k-ft)	Corr. A. F. (k)	Mu (k-ft)	Ma (k-ft)	phi	As (in2)	1.2Mcr (k-ft)	Load Ratings IR (Str I)	Load Ratings OR (Str II)
LT	7.00	-1.45	2.48	5.13	5.15	0.90	0.14	10.59	6.07	7.87
MID	45.00	6.20	0.41	9.74	8.85	0.90	0.27	10.59	1.59	2.06
RT	7.00	-7.48	1.41	11.39	10.54	0.90	0.32	10.59	1.56	2.02

Windows Standard Toolbar

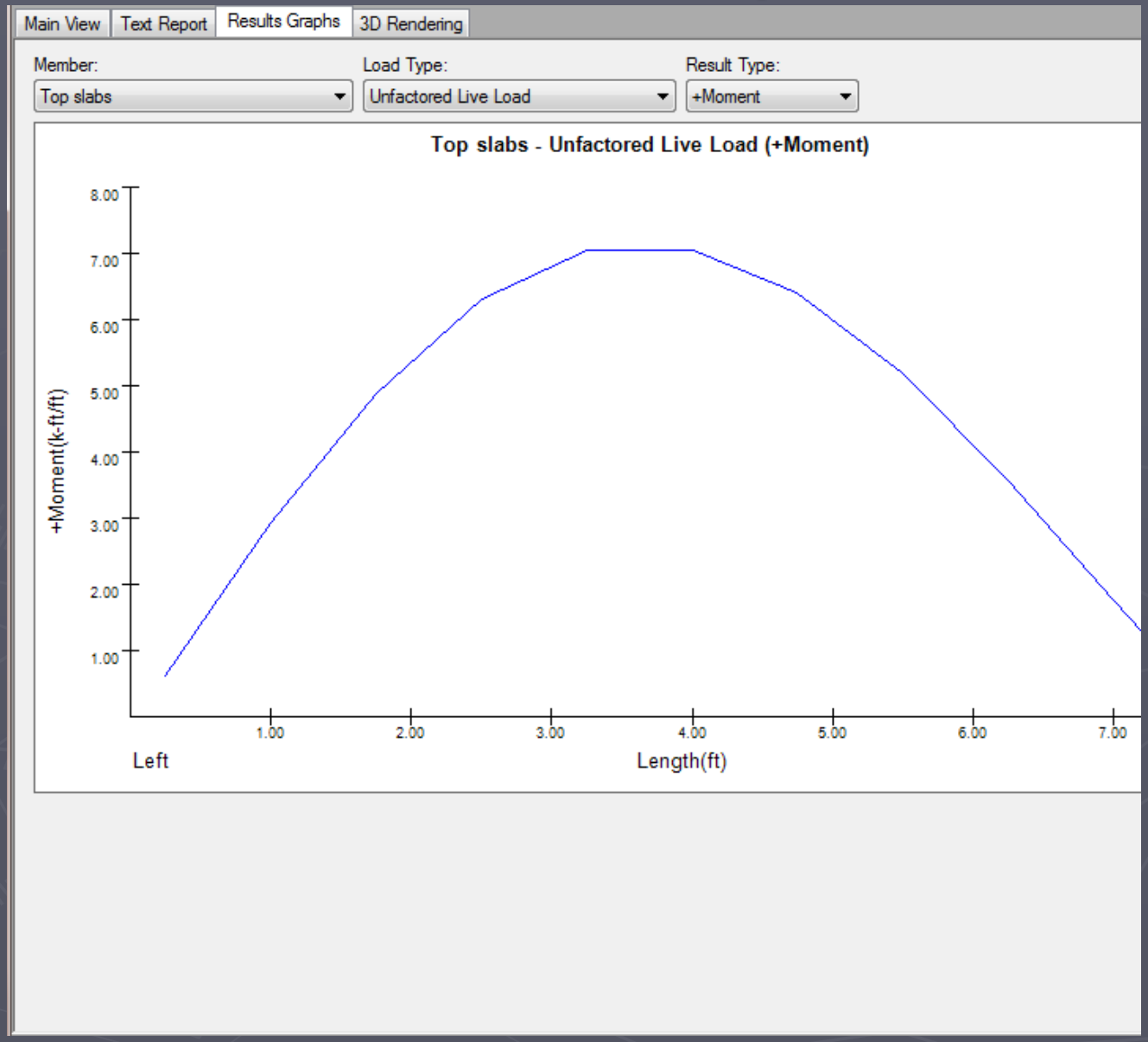


Defining Trucks

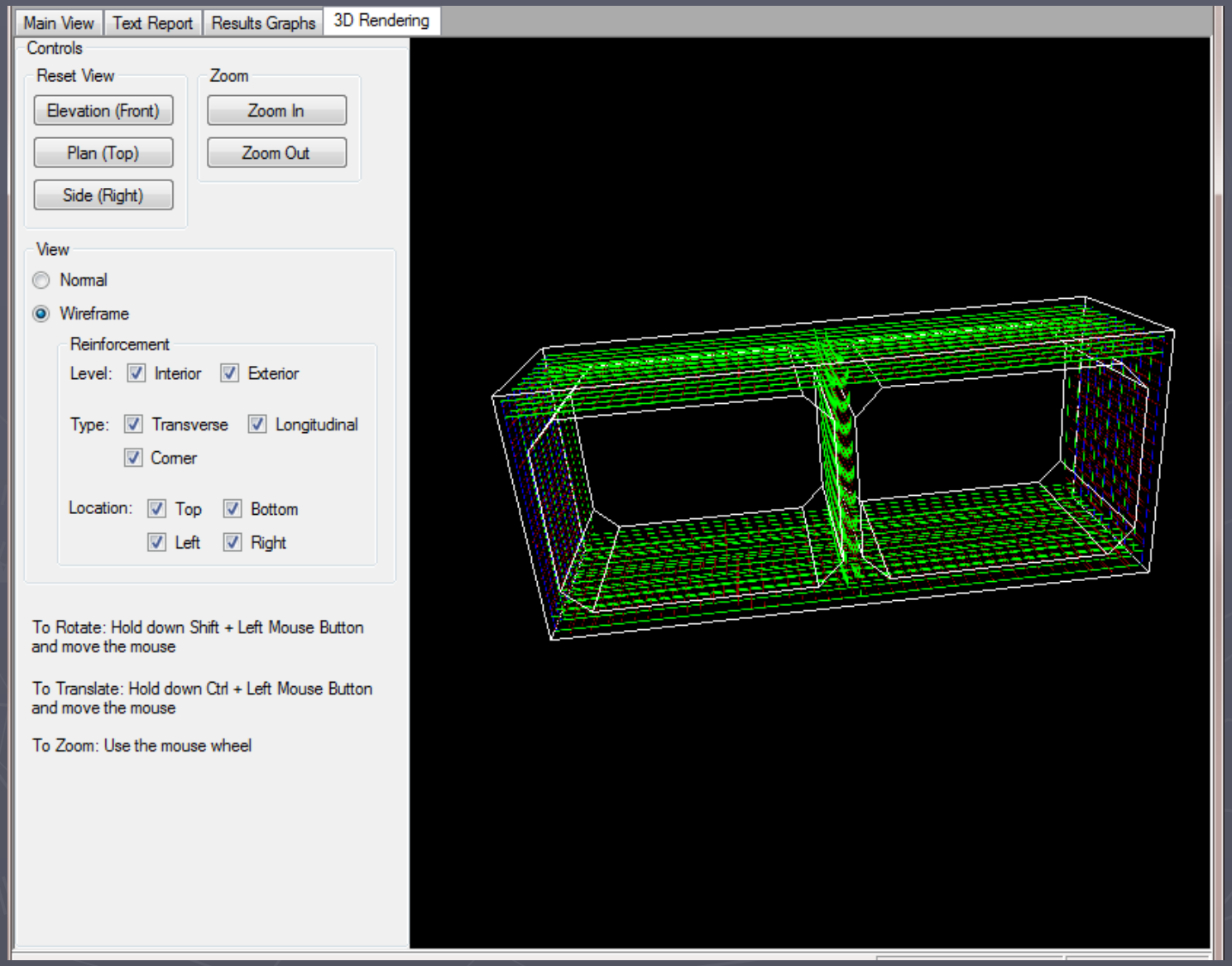
- ***Variable axle spacing and magnitude***
- ***Also define lane and tandem loads***



Results Graphs



3D Rendering

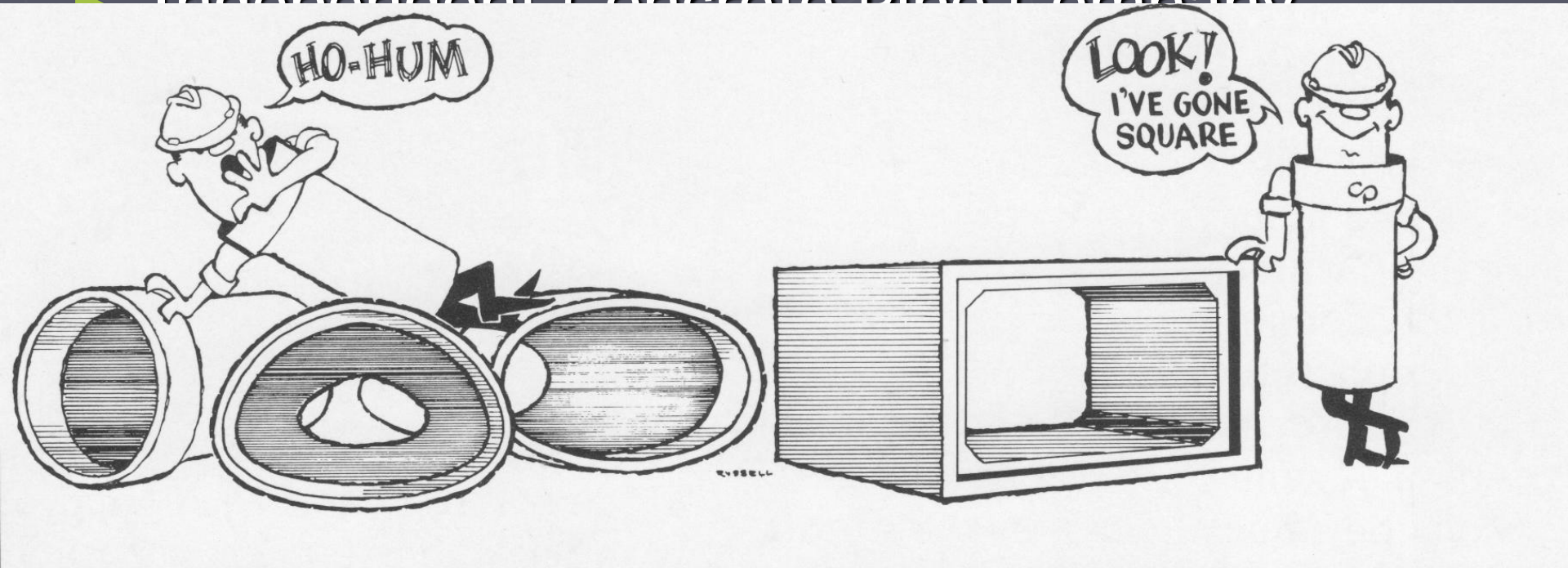


Future Plans for ETCulvert

- *Include support for more sophisticated structural analysis options*
- *Add soil-structure interaction*
- *Add support for Canadian Highway Bridge Code*
- *Allow access to reinforcement size/spacing pair library*
- *Add wingwalls, footings, appurtenances*
- *Additional user requests and agencies*
- *Support for AASHTOWare*

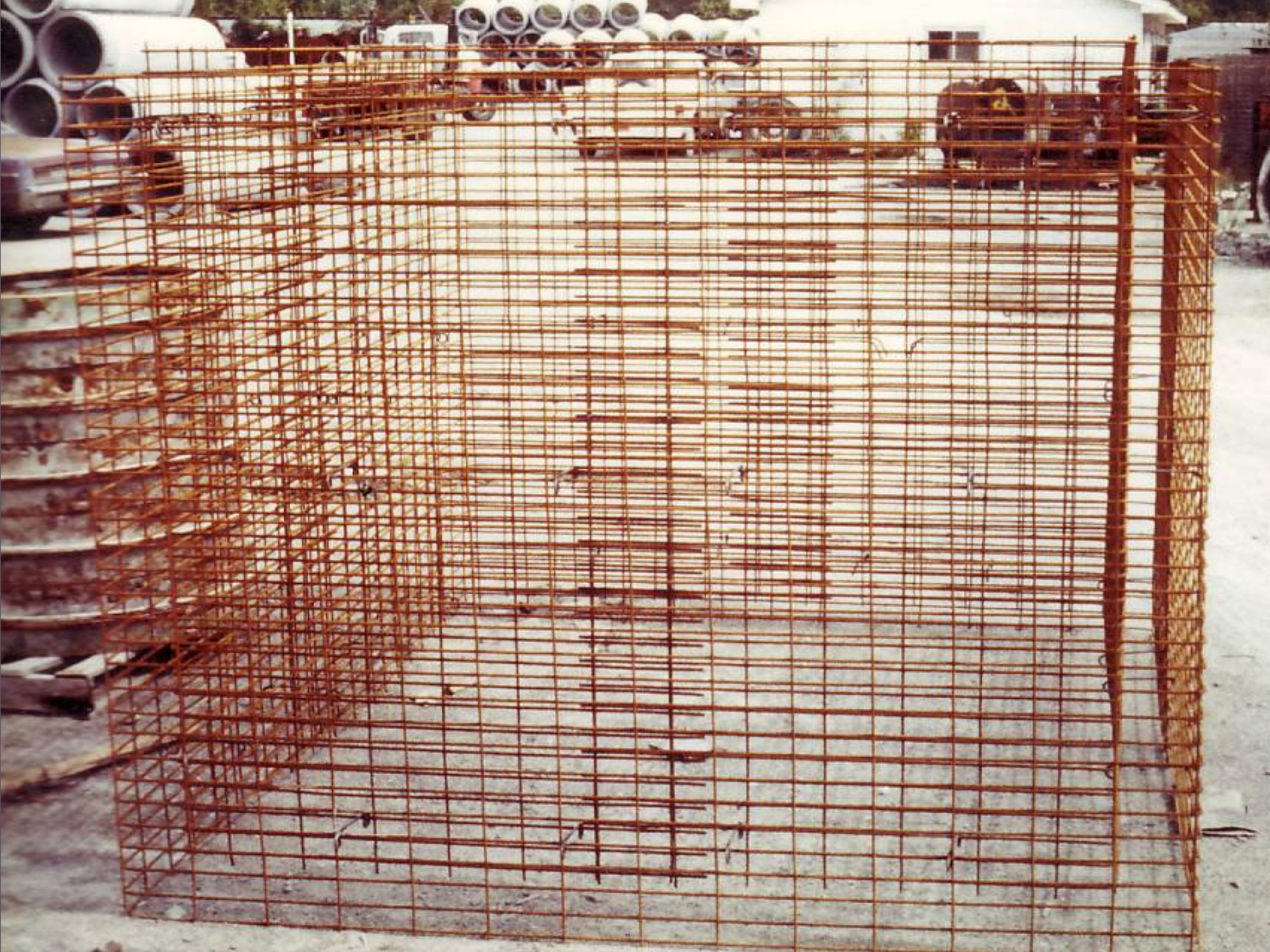
BOX CULVERT INSTALLATIONS & APPLICATIONS

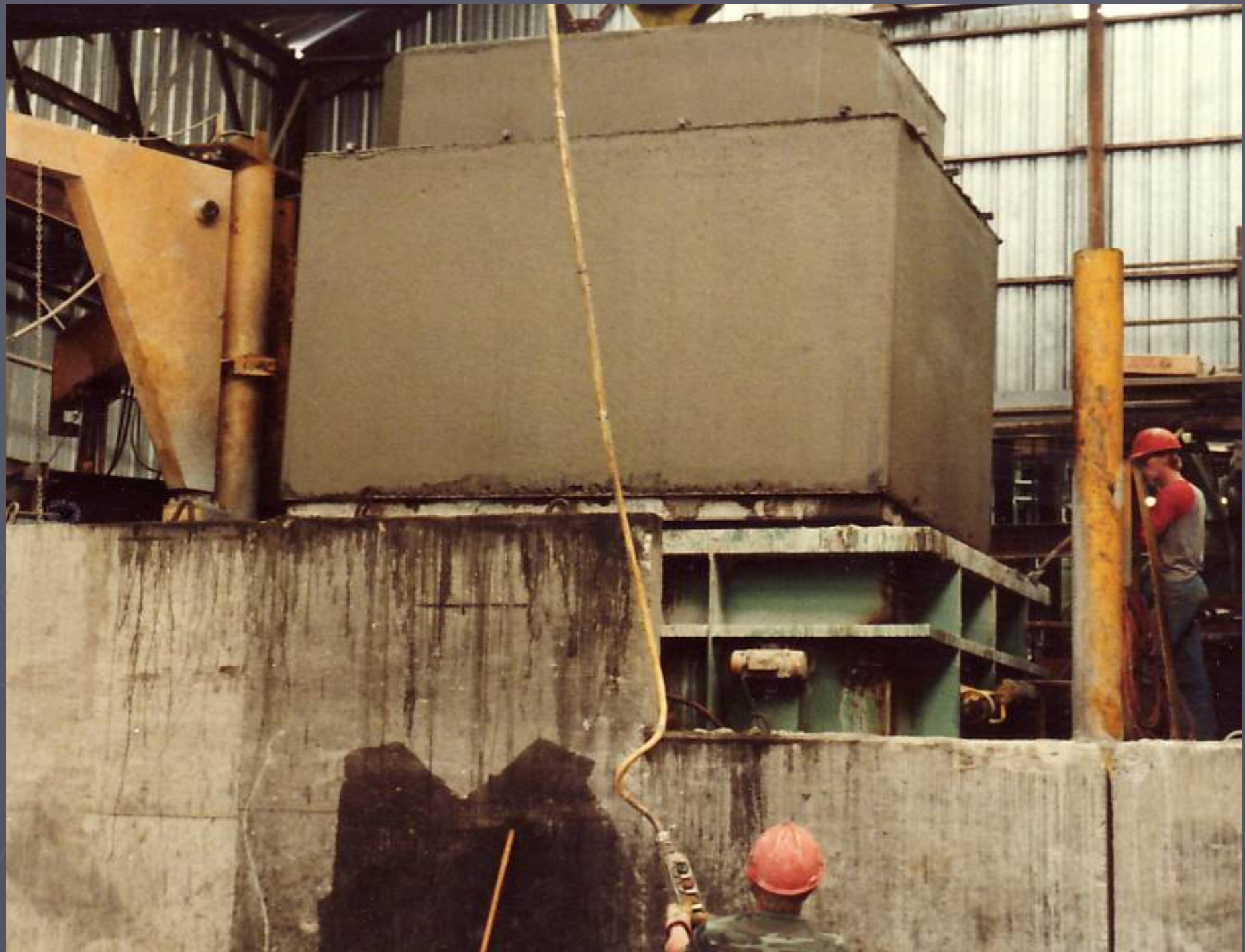
- Steven R. Smart
- Director of HY-SPAN® Bridges and Structures
- Independent Concrete Pipe Company

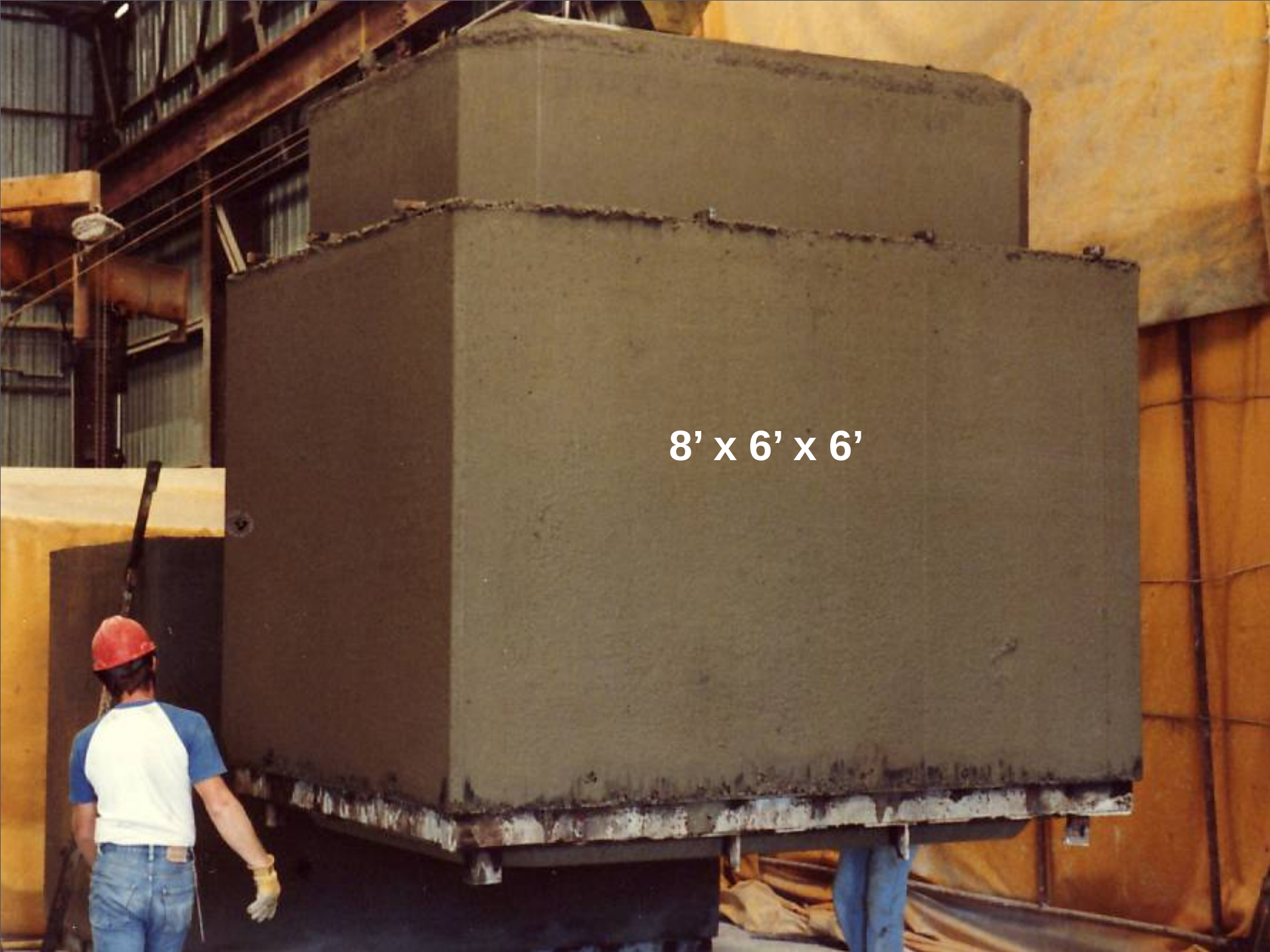


Precast Box Culvert Production

DRYCAST METHOD






8’ x 6’ x 6’

Precast Box Culvert Production

WETCAST METHOD


6 22 05


19’ x 3’ Oversize Box Culverts

- **Pre Site Inspection**
- The site should be evaluated prior to starting the work
- Check which way is the best way to access the culvert to be installed
- Check for overhead utilities contact utility companies about covering or relocating lines if needed well in advance
- Locate any buried utilities to check for conflicts
- Run routes for trucking to make sure you can get trucks to the site

Shop Drawings

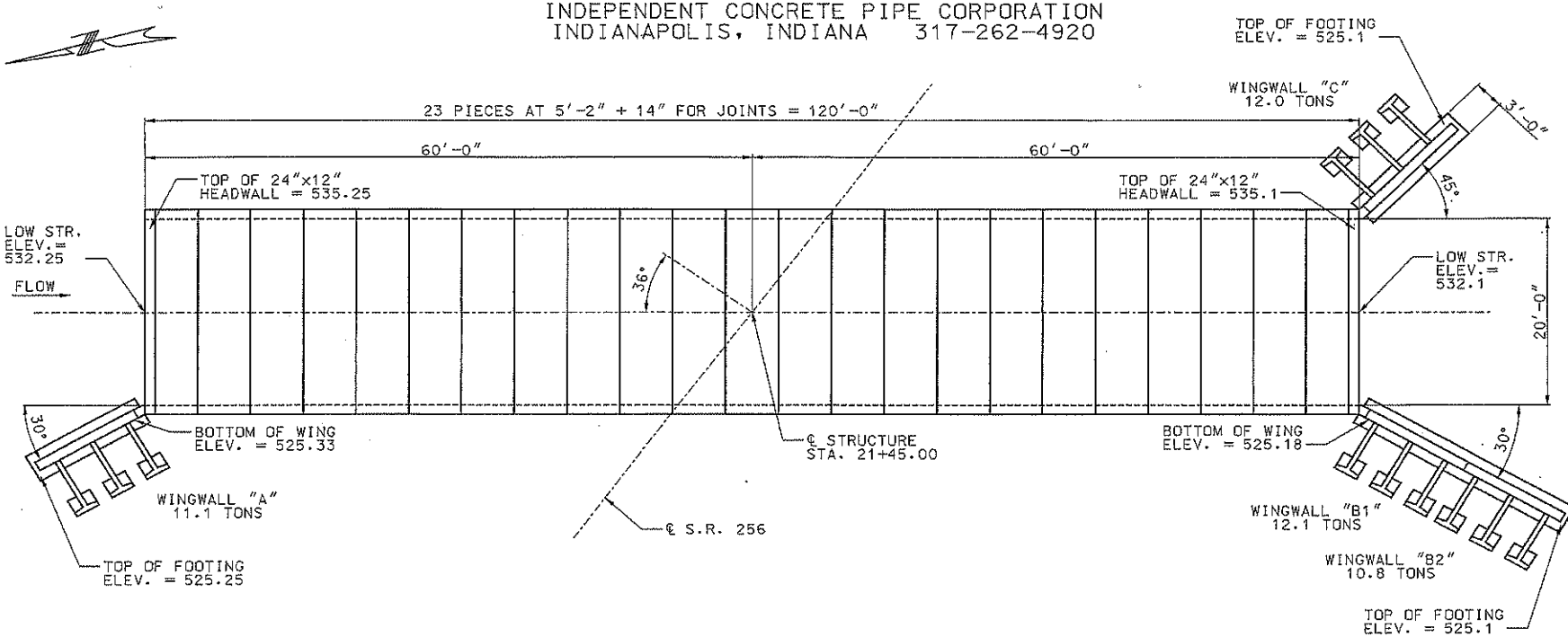
Shop drawings and plan details will determine the dimensions and elevations of the structure.

Shop drawings for spans 12’ and smaller are not required unless the rise or design cover height is outside or not listed in the tables established by ASTM-1577 for Precast Box Culvert Sections designed for LRFD. (714.04c)

Wingwalls and headwalls require shop drawings showing elevations and design calculations.

Per section 105.02 shop drawings shall be signed and sealed by an Indiana Professional Engineer and submitted to INDOT for approval.

INDEPENDENT CONCRETE PIPE CORPORATION
INDIANAPOLIS, INDIANA 317-262-4920



NOTE: TOP OF WING FOOTINGS AT BOTTOM OF BOX CULVERT.

GENERAL NOTES

THE DESIGN CONFORMS TO LOADING IN ACCORDANCE WITH THE 2010 AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS, 5th EDITION.

MINIMUM 28-DAY CONCRETE COMPRESSIVE STRENGTH SHALL BE 5000 PSI.

REINFORCEMENT SHALL BE WELDED WIRE FABRIC CONFORMING TO AASHTO M55 (ASTM A 185) SMOOTH OR (ASTM A 496) DEFORMED WIRE.

HEADWALL DESIGN LOADING:
ACTIVE EARTH PRESSURE = 40 PSF
LIVE LOAD SURCHARGE = 2 FEET EQUIVALENT SOIL HEIGHT, WHERE REQUIRED

TOP OF WING SET AT TOP OF HEADWALL.

BOTTOM OF WING FOOTING 3'-0" BELOW BOX CULVERT.

ROBERT J. LOBITZ REGISTERED No: 69018240 STATE OF INDIANA PROFESSIONAL ENGINEER
7/11/12

ABNA STRUCTURAL DESIGN ADEQUACY

S.R. 256 OVER STINK DITCH

PROJECT/DES.	0710867	COUNTY
CONTRACT	B-30235	STATION

GENERAL LAYOUT

SPAN 20' x RISE 6'-0" x WALL 12"

DATE: 7/11/2012 SHEET

J:\2012\000 Pending Job Number\111 20x6 Bx Alt • Arch Wings -HW\Cadd\GI 20x6 Layout.dgn

Installation

- Subgrade line and grade verified and established.
- The grade and alignment should be established prior to setting the boxes. The alignment of the first piece should be carefully laid out so the section can be set as close as possible. The outside corners at the end of the box with a line down one side is the best way to insure the alignment stays consistent. Be sure to check the plans and shop drawings for grade to determine if the structure is sumped and the flow line elevation is proper.

Unloading Product


Bell only
Down stream END
15’ x 7’ x 6’


Bell
only
Downstream
END


Bell
Down stream
END
only


Bell
Down stream
END
only

Installing process

Once the line and grade has been verified then the first section can be set in place. A string line or paint line running on the outside edge of the box is the best way to maintain alignment. It is necessary to spend as much time needed to insure the first piece is on the proper line. This will make all the other pieces easier. After the first piece is set a small trench at the bell end should be dug so as not to roll up stone or sand into the joint of the next section.


20X6X5
ID


20X6X5

Methods used to home joints

- Pullers made especially for this type of work
- Come-a-longs used on both sides of the box
- Equipment pushing from the front or side


650J
LGP
DEERE


650J
4046


RAGLE
INC.
DEERE


DEERE
200LC


RAGLE
INC.
20X8X5
20X8X5
DEERE

20’ x 12’ x 4’ Oversize Box Culvert


DEERE


DANGER
DANGER


18’ x 8’ x 5’


KOMATSU


15 6 '06


THE

Laying backward

18' x 10' x 4.5'


4.7


4.7

Importance of staying on line and grade

- Every box should be checked for alignment and grade
- Once it gets off it's nearly impossible to get back


Maxwell
WALSH


888 203-4500
CAT
PINCH POINT


OVERSIZE LOAD


AUSTI
MAC

Completion of joints

- Bituminous mastic sealant applied prior to jointing of box culverts (907.11 b)
- Joint membrane system in rolls a minimum of 12” width (907.07) example: Polyguard 175 or material meeting ASTM 877 for External Wrap
- The surface should be clean and dry in order for the wrap to stick properly
- In cold conditions it may be necessary to heat the wrap to make it stick

Headwall and Wing Wall Installation

- Establishing grade for wings
- Rigging of wings
- Bolting of wings to box sections
- Installing detached headwall


HYSTER
037553


A or C


A or C


B or D


WWB2


TL140


Headwalls
SHDW
165 TON


Down stream
END
Bell
only


Certified
1-800-997
ENTAL
C0737


CF-1 Guardrail


DEERE


165 TON
DEERE
AB ONYETT
MACHINE
WELDING
DEERE
NHDW


19’ x 3’ x 6’ with sidemount guardrail
2011/06/11

Skewed ends

MITRE 12’ X 4’ BOX CULVERT SECTION


SMITH
Erectors, Inc.
260-758-2273
INDIANA
129937
5132


CAT
325B

Backfill and Compaction

Uniform Lifts with approved material not to exceed 24” on either side (714.05).

Check minimum cover for equipment traversing structure, normally 2 lifts.


CAT


10 21 97


5 16 12
8550
20X8X5
5 14 12
8550
20X8X5
5 14 12
8550


DEERE

Special applications


81
615-TAY


8’ x 6’ x 6’ with 30” hole


18’ x 6’ x 6’
36” RCP- actual 50” dia.


Thank goodness it was precast!


Even producers have problems with boxes at times


Alcohol...
Because no great story starts with a salad.

THANK YOU !

?’s