BOX CULVERTS

ALABAMA VIRTUAL SERIES

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American Concrete Pipe Association

BOX CULVERTS

Alabama Virtual Series

Learning Outcomes

1. Describe the basic fundamentals of precast drainage structures
2. Box Design-Example
3. List the necessary steps to properly install box culvert
4. Discuss the options available for box culvert end treatments
5. Describe how manufacturers are able to provide “specials”
6. Discuss the key tenants of Accelerated Precast Construction

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Course Agenda

Precast Structures

Fundamentals

Precast Structures: Fundamentals

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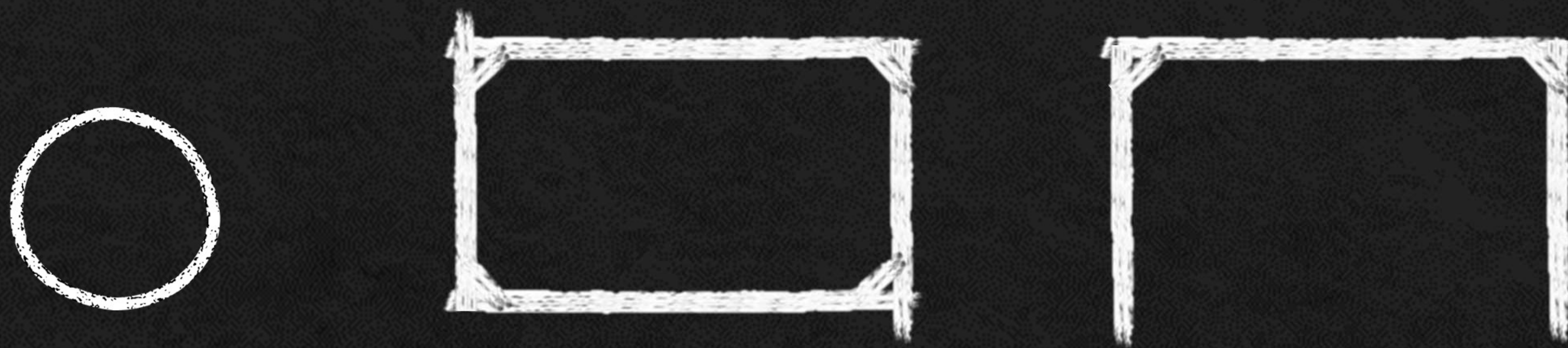

Pipe
ASTM C76

4 Sided Box
ASTM C1577

3 Sided Box
ASTM C1504

Precast Structures:
Fundamentals

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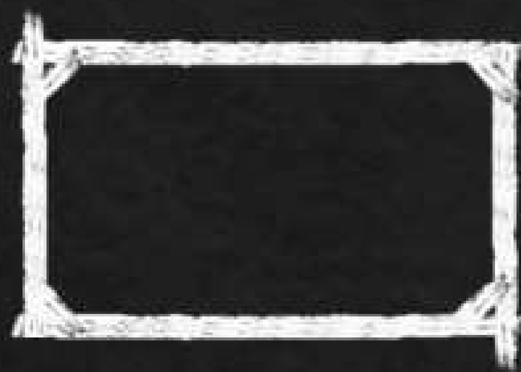
Pipe

ASTM C76

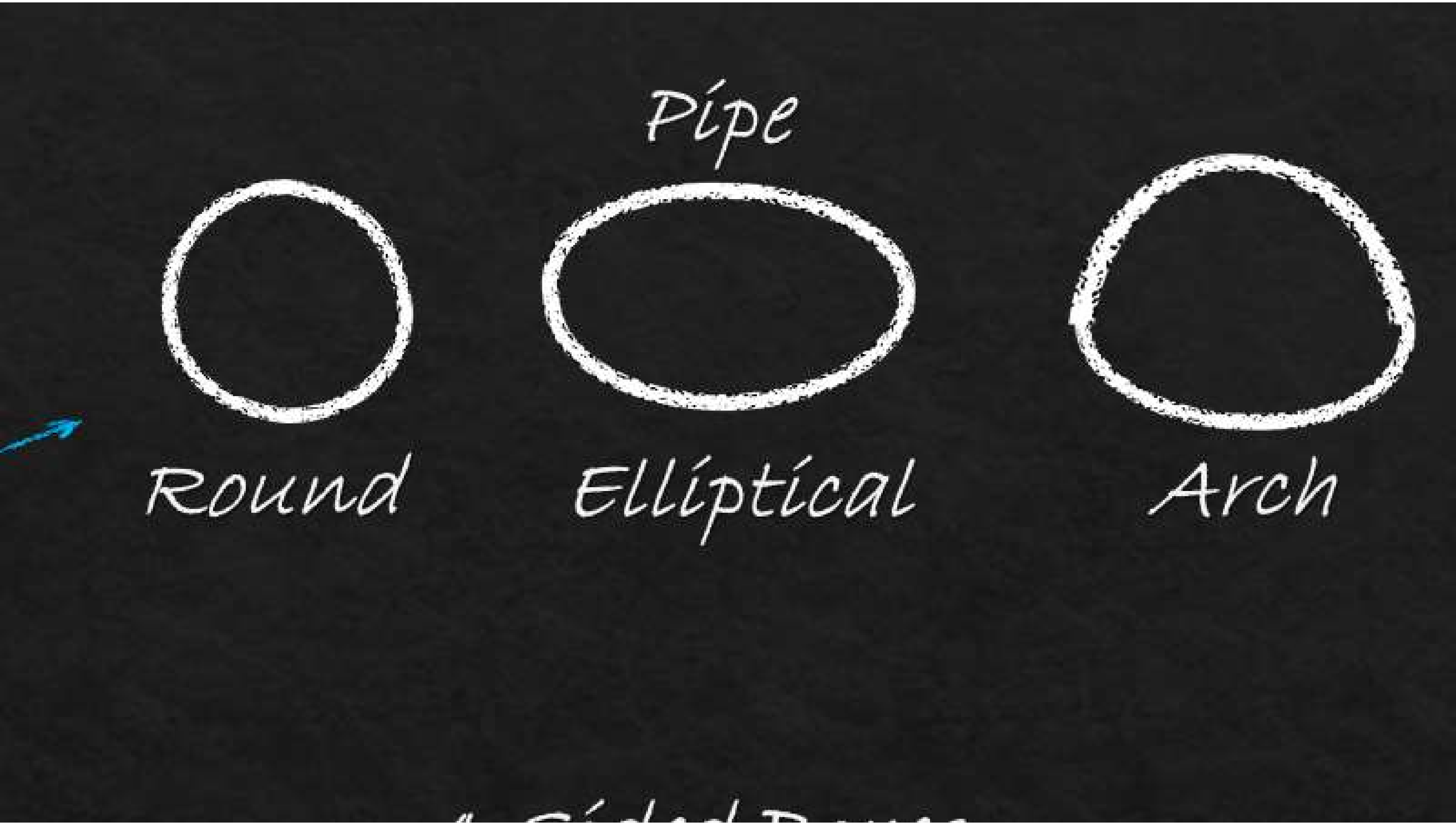


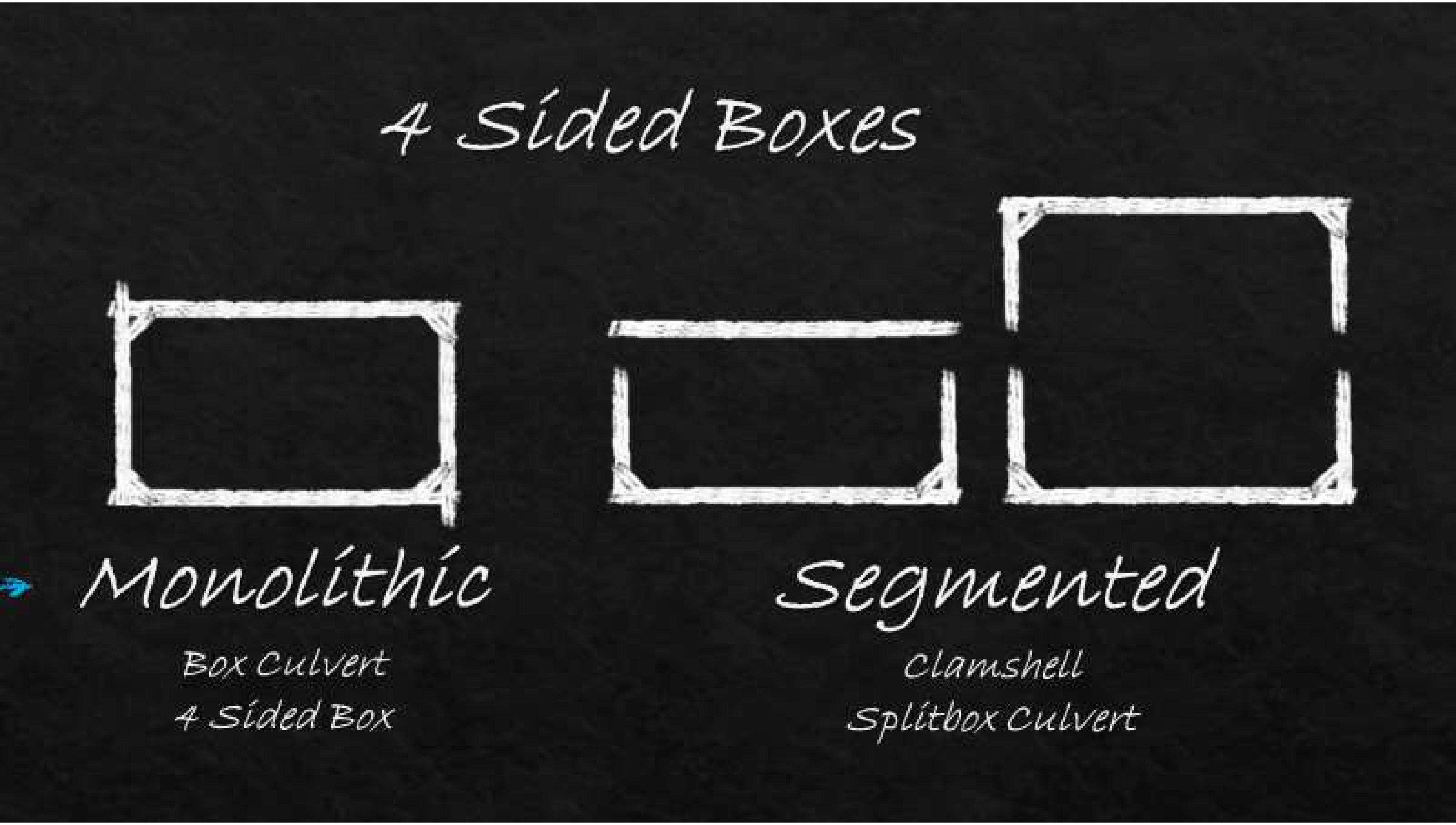
4 Sided Box

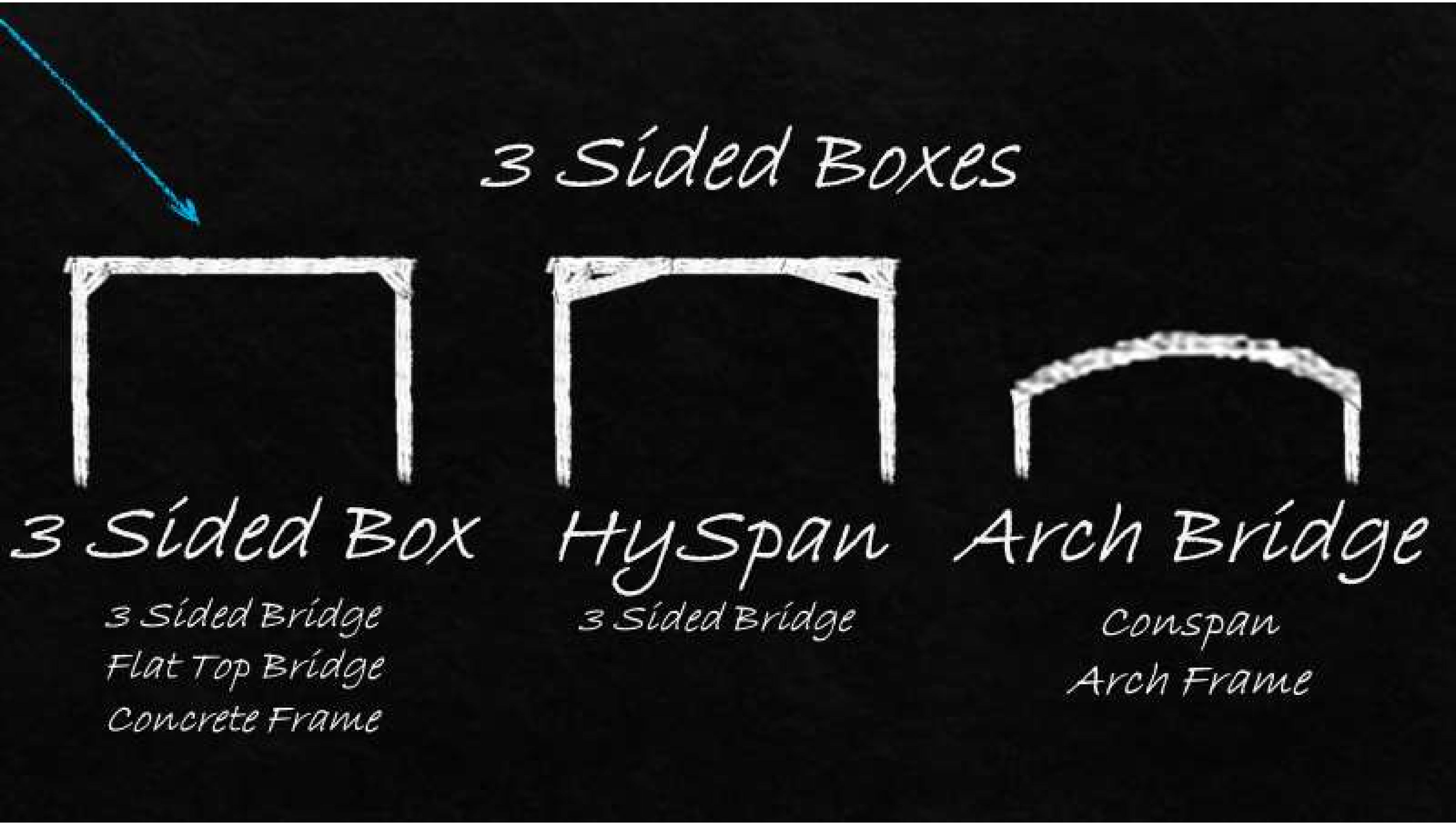
ASTM C1577

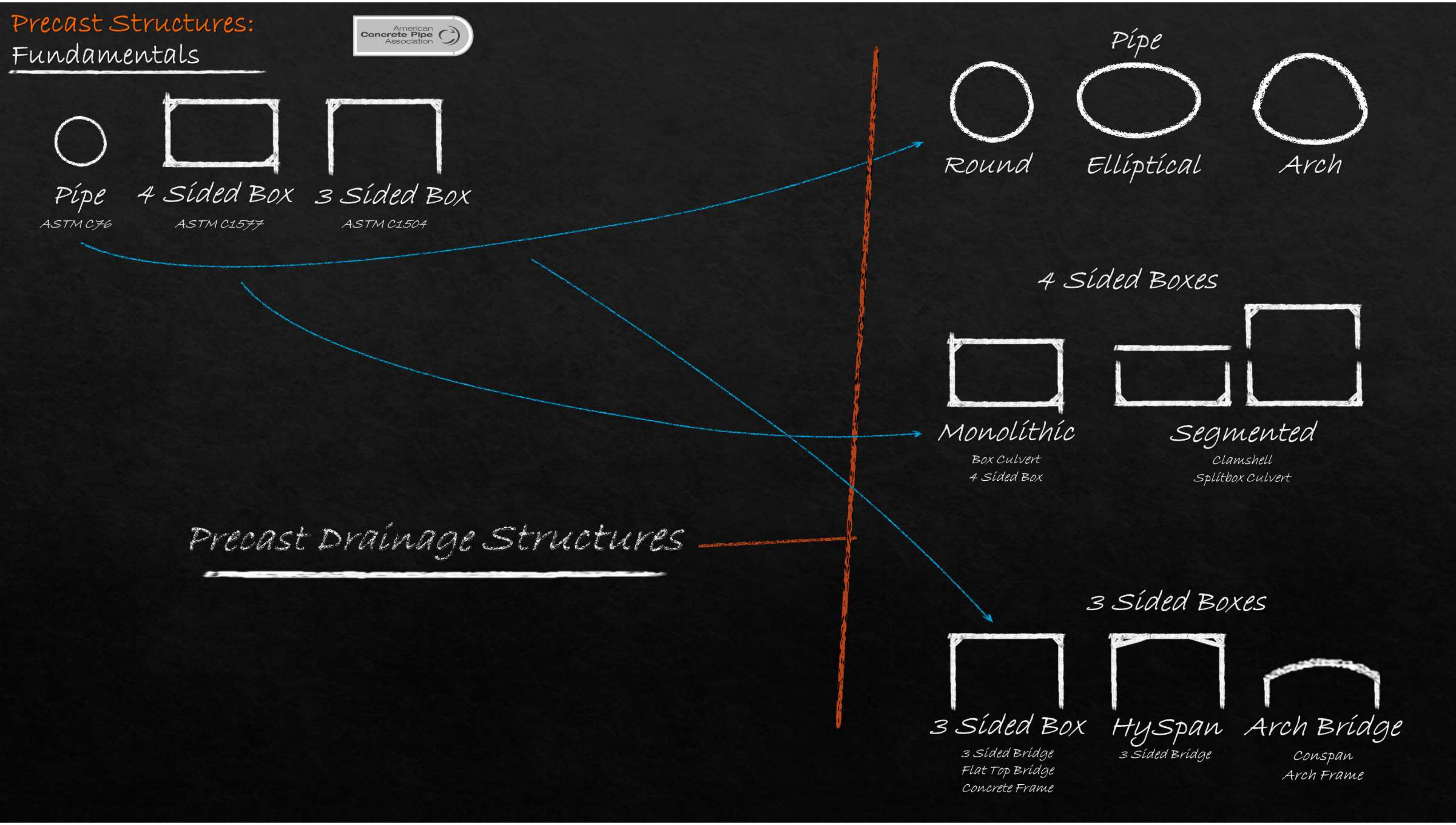
3 Sided Box

ASTM C1504


Pipe
Round
Elliptical
Arch


4 Sided Boxes
Monolithic
Box Culvert
4 Sided Box
Segmented
Clamshell
Splitbox Culvert


3 Sided Boxes
3 Sided Box
3 Sided Bridge
Flat Top Bridge
Concrete Frame
HySpan
3 Sided Bridge
Arch Bridge
Conspan
Arch Frame


Precast Structures:
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ASTM C76
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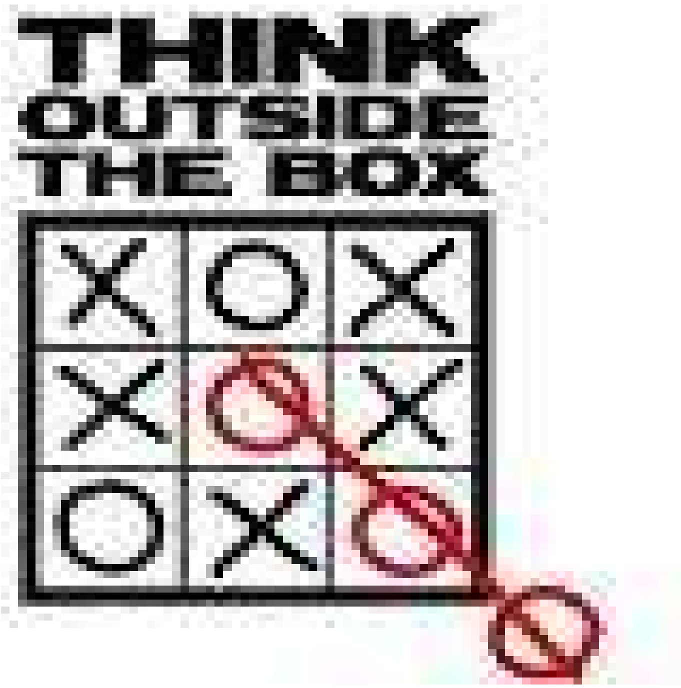
Goals for Today

Let's Put on Our "Thinking Caps" about *applying todays lesson* to current or future jobs

Much has been said about:



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- Today – we'll be thinking
- **About the Box itself**

Why do we need to Replace & Add Culverts:

- Alabama Facts:
- Total of over 100,900 miles of *paved* roadways
- Over 77,000 miles of rivers and streams

+

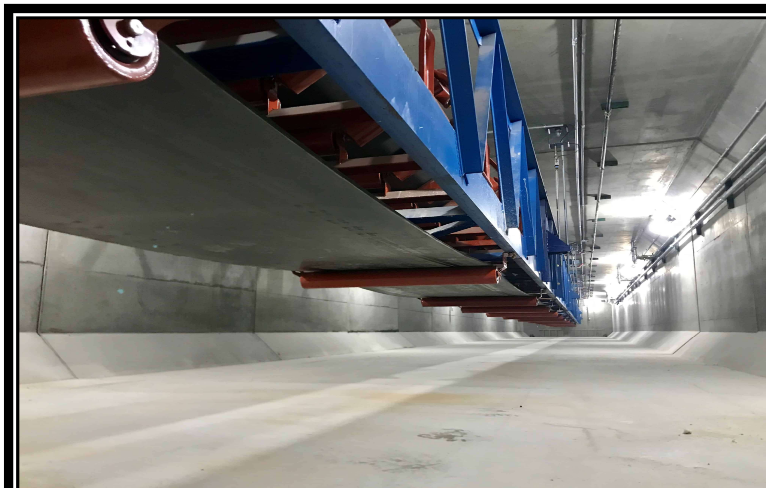
=

Durable Reliable Infrastructure

Box Culverts:

Note: Box Culvert ≠ RCP²

- **<u>Standard, and Non-Std. uses</u>**
- **<u>Beyond Bridges and Culverts:</u>**
- Large Capacity Detention
- Pedestrian, and Wildlife Tunnels
- Junction Chambers:
- Large Capacity Pump Stations –
  - *Vertical Application (we'll see an example near the end)*
- Underground Conveyor Systems:
  - Aggregate suppliers



- "Preppers" – Bomb Shelters
  - (yup, where better to spend the rest
    - of your days!)

Durable **Reliable** Infrastructure

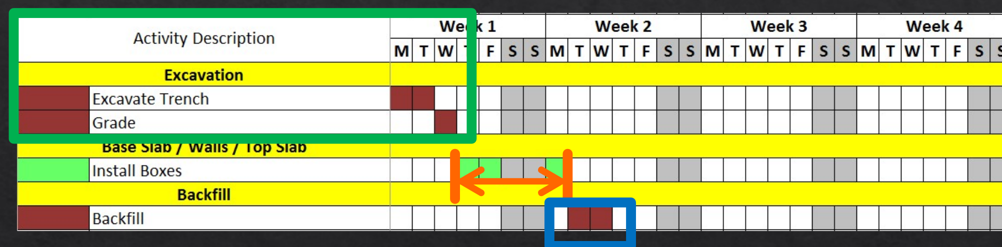
Durable Reliable Infrastructure

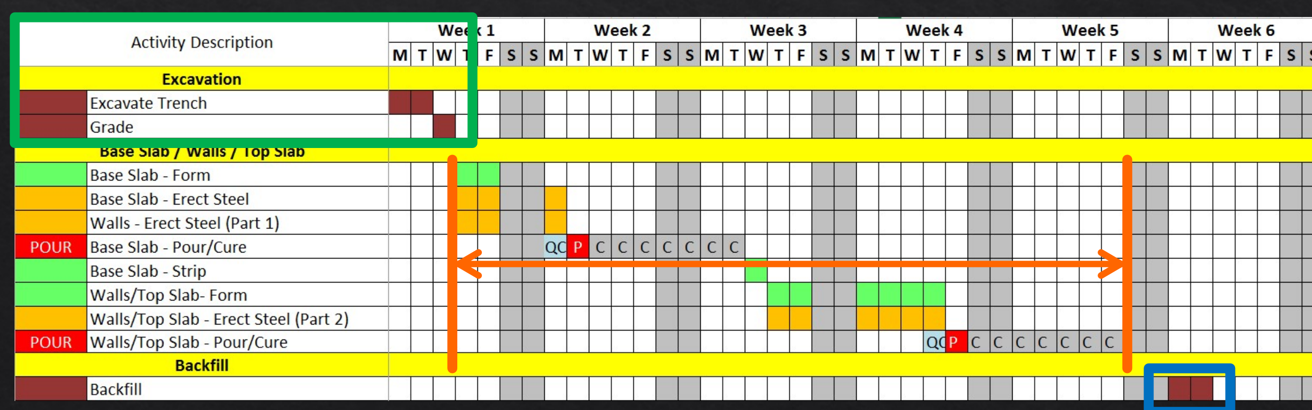
Detention Systems:

- Most efficient shape
- Large detention volumes
- Meets highway loadings

- Little to no cover required

Precast Structures:
Advantages

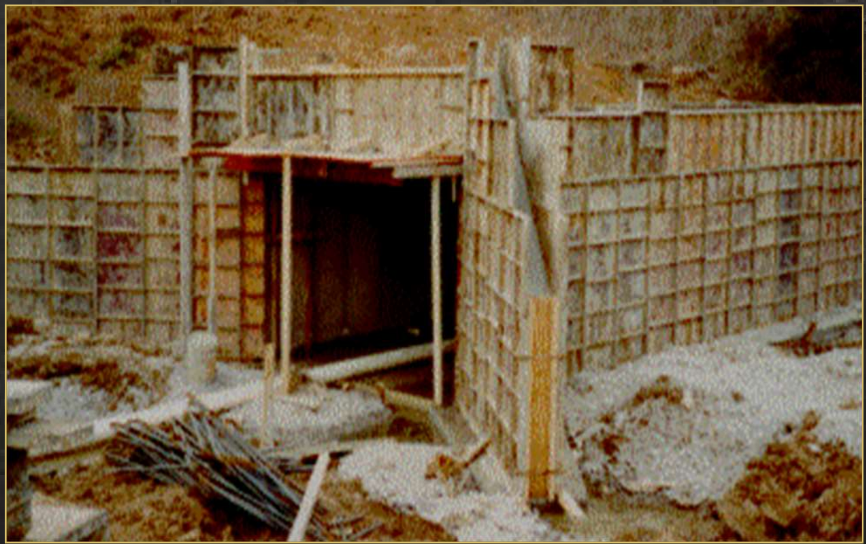




Precast Structures:

Precast Vs Cast-in-Place

- Consistent dimension tolerance



Environmental Exposure


Everyday you're near the creek
setting forms-tying steel – pouring concrete-
waiting for cure time-stripping-
You expose yourselves to Environmental Risks!

Precast Structures:

Precast Vs Cast-in-Place

- Weather resilient construction

Speed, Safety, Less Environmental Impact , Less Liability– You Pick?

Precast Structures:

Advantages

- Controlled Curing Environment
- Removal from the Critical Path
- Potential for Reduced Cost
- Lower Weather Dependency
- Simpler Construction Methods
- Accelerated Project Completion

Why Box Culverts?

- Basic Box (C1577): 3x2 up to 12x12
- Custom sizes
- Multicell
- Large spans
- Shallow/ Deep fills (0 to 300 ft)

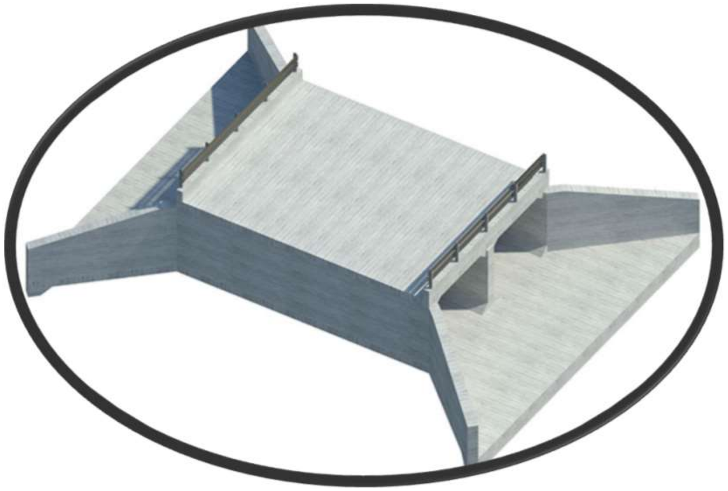
Foley Concrete Products.

Box Design: Guiding Design publications

AASHTO: Section 12

LRFD Bridge Design Specifications

ASTM C-1577



Durable Reliable Infrastructure

Box Culvert Design: *Considerations*

- Peak Flow Events:
  - Pipe Size, Slope, Entrance Type, Freeboard, Ponding
  - Inlet / Outlet Control Rainfall, Watershed Modeling
- Economics:
  - Life Span, Installation, Cost of Structural Damage, Replacement Costs
- Legal Requirements:
  - EPA, Forest Practice Regulations, Construction Timing
- Fish Passage:
  - Migration Period, Water Velocity, Pipe Inlet Geometry, Water Depth
  - Stability of Outlet Pool
- Maintenance:
  - Woody Debris, Bedload, Maintenance Funding, Scour Effects

Box Culvert Sizing:

Determining required Waterway Area (sq. ft)

- -Estimate Peak Discharge 100yr flood using:

- 1)---Rational Method (most commonly used method)
  - --Assumes Entire Basin has Uniform Constant Rainfall Intensity until the design discharge a the crossing is achieved.

- 2)---**USGS Magnitude and Frequency Method**
  - equations developed from actual precipitation
  - and runoff data collected

- 3)---**Flow Transference Method:**
  - -Flow can be determined for streams that are nearby a
  - hydrologically similar watershed
    - -With a Long-Term gauging station.

- 4)---**Using FHWA Culvert Capacity Nomograph:**
  - -Sizing determined by calculated stream flow and headwater depth
  - = (headwater / diameter) ratio.

Hydraulic Modeling w/HY-8-it's free!

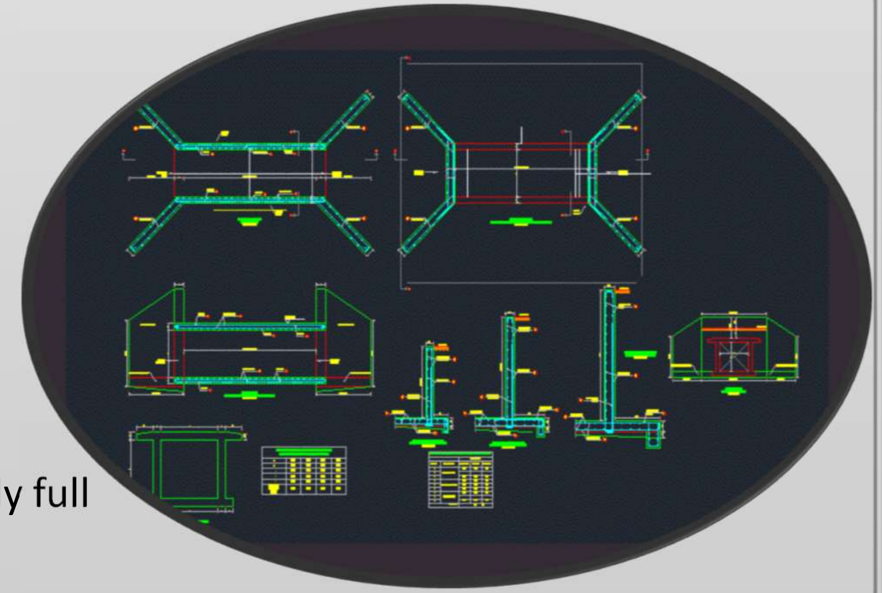
- Hydraulic computation Model for roadway stream crossings (Culverts)
- Created and Provided Online by FHWA:
  - https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/
- Allows users to:
  - Allows for multi-barrel crossings and multiple crossing in 1 project*
  - Analyze roadway Overtopping (weir flow over road)
  - Analyze the performance of culverts (velocities, water depths, flow profiles)

  - HEC-RAS

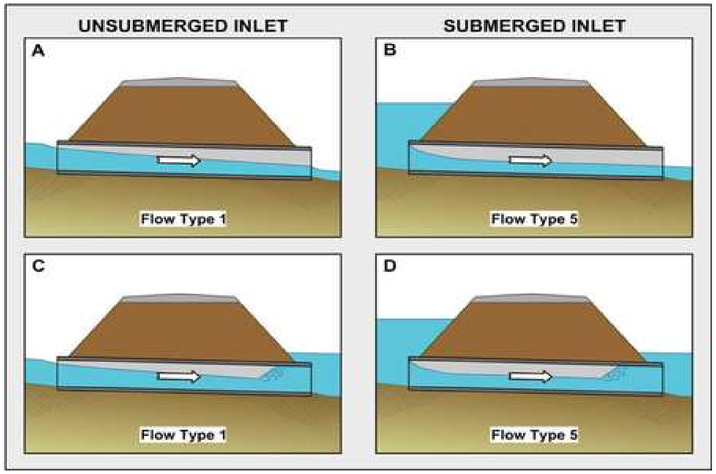
Let's Design A Box…

- Early Design Considerations:

- Flow Controls:
  - *Inlet Control—*
    - *Often w/Steep Slopes*
  - *Outlet Control—*
    - Often runs full, or partially full



Inlet Control:



- Inlet Control:
  - Culvert will convey more flow than the inlet will accept
- Parameters required to determine Dia. / End Area:
  - Design Flow Rate
  - Maximum Allowable Headwater Depth
  - Culvert Slope
  - Type of Inlet:
  - Type of Culvert Material: RCP, Box Culvert, Other.. **

Outlet Control:

- Outlet Control:
- OC=water enters faster than it flows through the culvert
  - Culverts w/O.C – often flow full, or partially full.
  - Parameters required to determine Dia. / End Area:

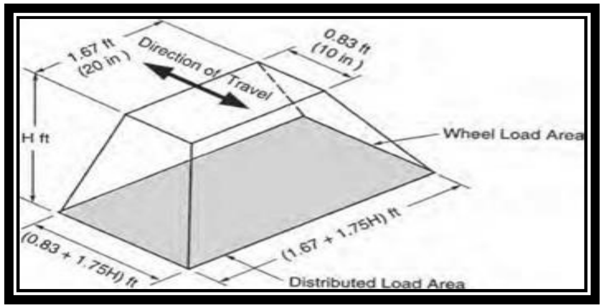
Same as Inlet Control
- Design Flow Rate
- Maximum Allowable Headwater Depth
- Culvert Slope
- Type of Culvert Material
- Type of Inlet

Add: Tailwater Height
- Length of Culvert

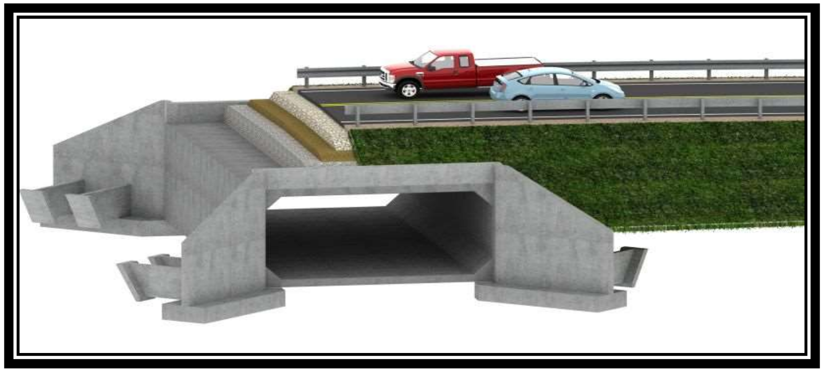
What We Need To Design A Box Culvert?

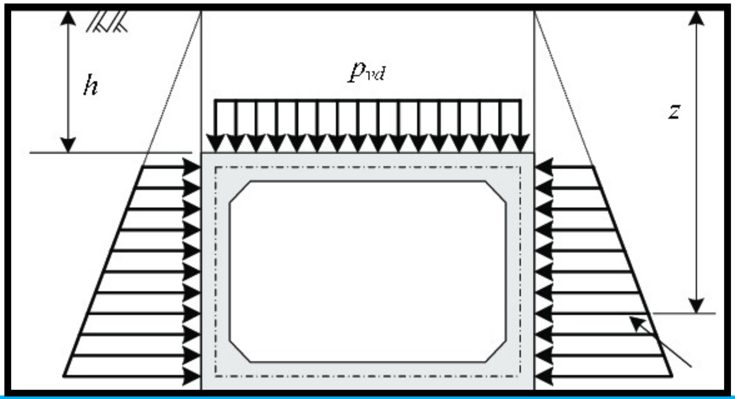
- Required "End Area*" -as determined by engineer
- Span– Rise (both in feet) (can be done in smaller increments)
- (* = "Net": lost end area from 12" x 12" "haunches" in corners)
- (Ex: 8' x 8' Box = 63.1 sq. ft)
- Fill Height: Top of box to top of road surface
- Live load -HL-93 or HL-93 mod
- Angle of box : Angle of road Crossing

Loading Considerations:



- Live Loads
- Dead Loads
- Lateral Earth Loads:
  - From Soil and
  - Hydrostatic Loads from Groundwater
- Vertical Loads:
  - From Cover and live loads
- Surcharge Loads:
  - From nearby impact loads
- Seismic loads (where applicable)





Culvert Loading:– Historical Nomenclature: Truck Design

- Historically called: HS-20 44 or (HS-25)
- (where H stands for highway,
- S for semi-trailer)
  - **20** = 20 ton weight of tractor
- 44= year adopted (1944)
- **Current Design Loading:**
- **A) HL-93 Loading**
- (where H stands for highway
- and L stands for Loading).
- (developed in 1993)
- **B) HL-93 Mod**
- *The design of this structure is based on 1.2 times the current AASHTO LRFD Bridge design specification HL-93 loading with the exception that the Design Tandem portion of the HL-93 Load definition shall be replaced by a single 60KIP axle load before application of this 1.2 factor –the resulting factors is designated HL-93 Mod*

AASHTO Section 12.11.1

- Li… …ribution (H<2'; H>2')
- M… …ads for soil st… …raction
- Di… …loads to…
- Se… th…
- Di…
- M… …of
- Minimum top slab concrete cover

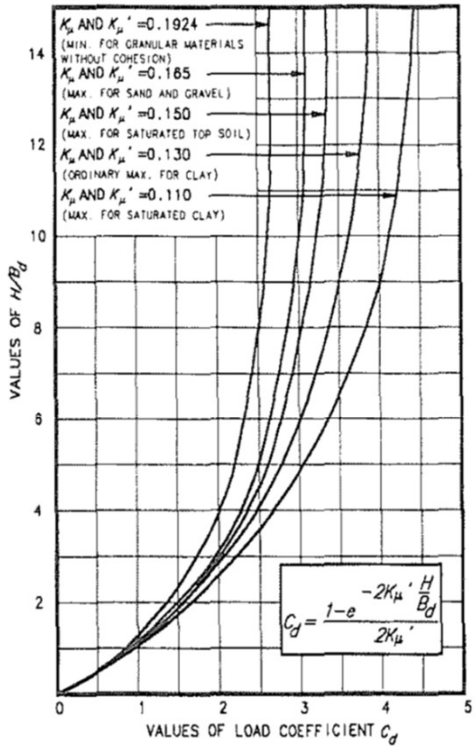


Figure 12.11.2.2.1-3 Coefficient C_d for Trench Installations.

(12.11.2.2.1-1)

$$20\frac{H}{B_c} \qquad (12.11.2.2.1\text{-}2)$$

$$f_s = \frac{M_s + N_s\left(d - \frac{h}{2}\right)}{(A_s jid)} \qquad (C12.11.3\text{-}1)$$

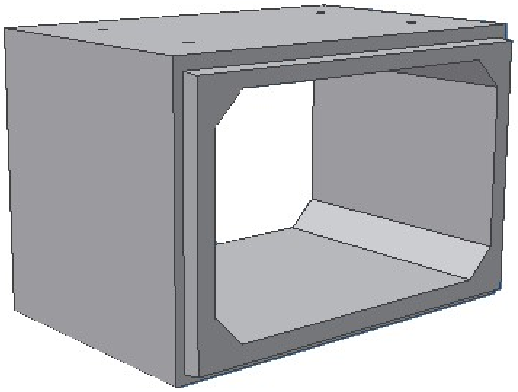
in which:

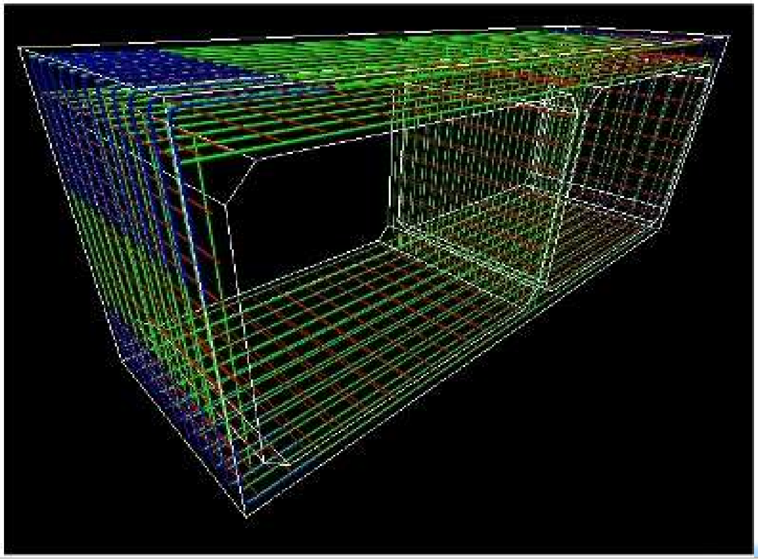
$$e = M_s / N_s + d - h/2$$

$$i = 1/(1 - jd/e)$$

$$j = 0.74 + 0.1(e/d) \le 0.9$$

BOXCAR SOFTWARE or ET CULVERT





- AASHTO / ASTM C1577 DESIGN
- 3D WIREFRAME GENERATION
- LOAD RATINGS PER C1577 & SECTION 12

Example: ASTM C1577

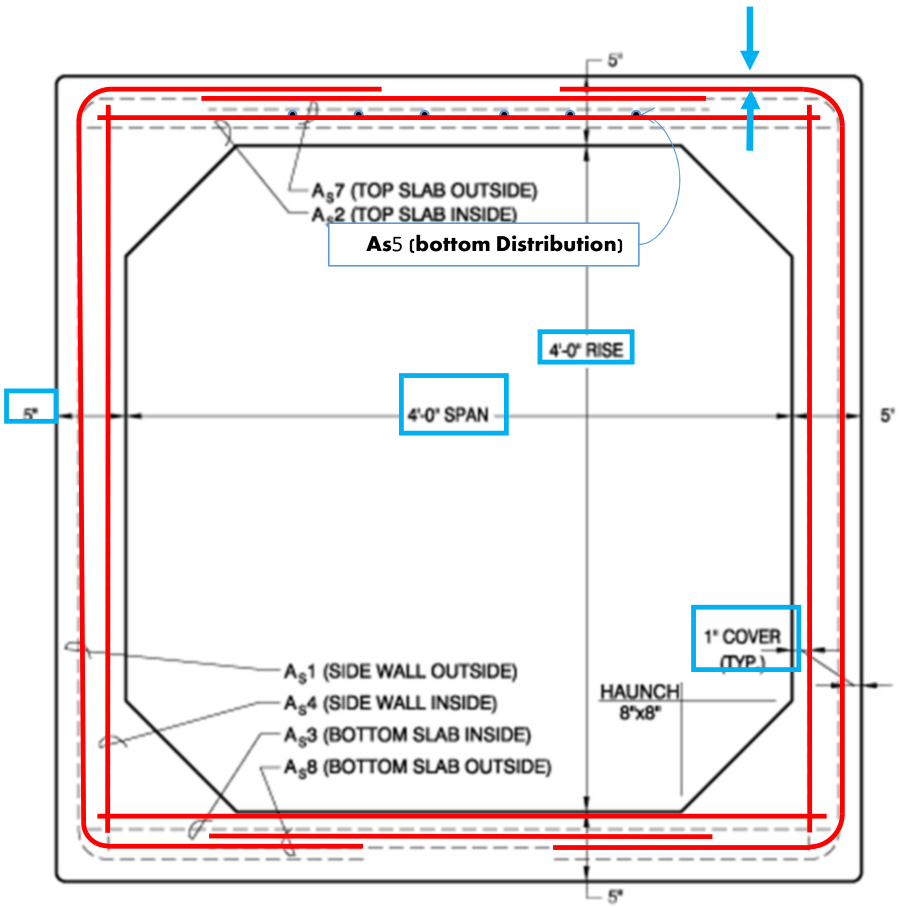
- 4' Span x 4' Rise (8" walls minimum)
  - Less than 2' of cover
  - HL-93 Live Loading
  - 5,000 psi Compressive Strength Concrete

Design Tables:

Design Earth Cover, ft	4 ft by 4 ft by 5 in.							
	Circumferential Reinforcement Areas, in.²/ft							
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.18	0.33	0.20	0.12	0.18	0.18	0.14	
2<3	0.12	0.26	0.23	0.12				38
3-5	0.12	0.18	0.18	0.12				38
10	0.12	0.15	0.15	0.12				38
15	0.12	0.19	0.20	0.12				38
20	0.12	0.25	0.25	0.12				38
25	0.14	0.31	0.31	0.12				38
30	0.17	0.37	0.37	0.12				38

Tabular designs in C1577 were prepared according to AASHTO LRFD Bridge Design Specifications

Example: C1577: 4'x4'x8" (8" walls is our min.)

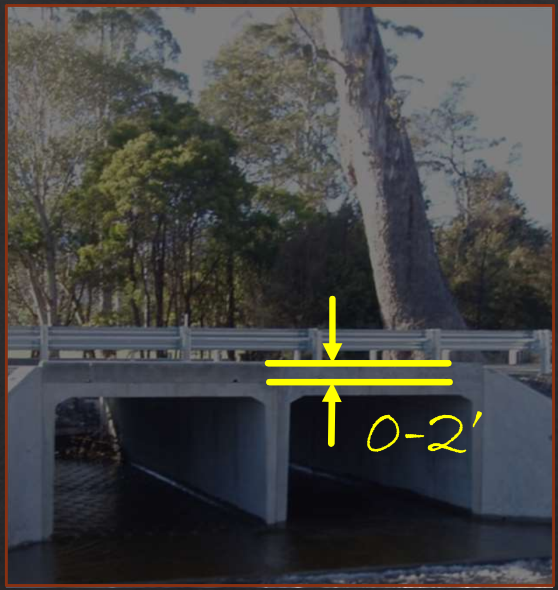


- 4' Span, 4' Rise,
  - 8" Walls
  - 1"- 2" Conc. Cover
- 5000 psi Concrete

- As1 (Side Wall Outside)
- As2 (Top Slab Inside)
- As3 (Bottom Slab Inside)
- As4 (Side Wall Inside)

- As5 (Top Slab Inside
  - Distribution)
- As7 (Top Slab Outside)**
- As8 (Bottom Slab outside)

Cover: 0-2'



AASHTO: M273
ASTM: C850

Cover: 2'+

AASHTO M259
ASTM C789

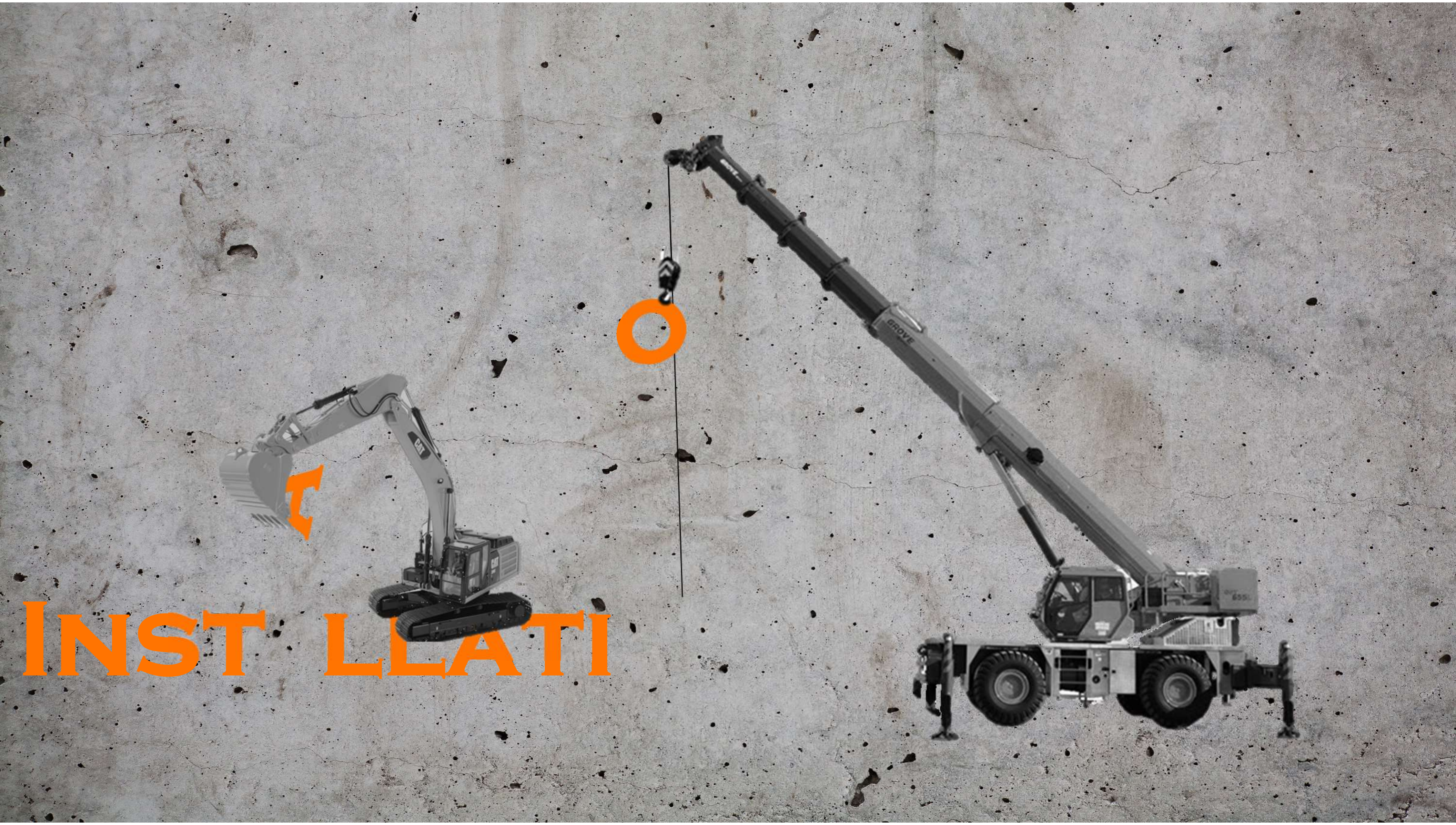
ASTM: C1433

LRFD → ASTM: C1577

Minimum Cover

0' cover:

- ❑ Maximizes hydraulic capacity
- ❑ Place road surface directly over boxes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TRENCH

EMBANKMENT

Installation Options


Lucerne County, PA 2014
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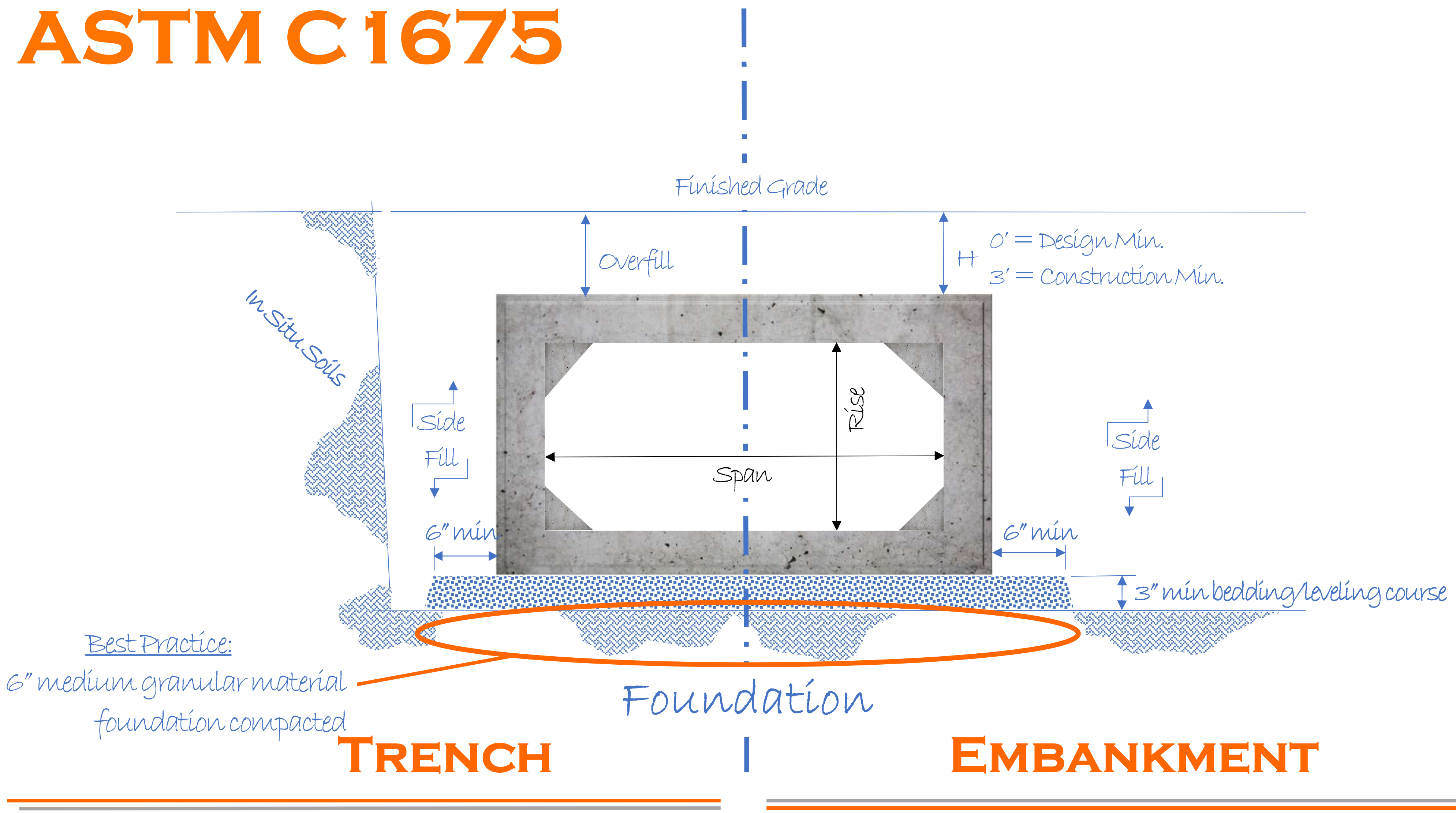
ASTM C1675



Finished Grade
Overfill
H
0' = Design Min.
3' = Construction Min.
In Situ Soils
Side Fill
Rise
Span
Side Fill
6" min
6" min
3" min bedding/leveling course
Best Practice:
6" medium granular material foundation compacted
Foundation
TRENCH
EMBANKMENT

Culvert Loading

- ❑ Earth
- ❑ Live
- ❑ Construction

Unless designed for construction loading, RCB backfill should be placed 3’ above top of box to accommodate construction loads.

Installation Best Practices

- Scheduling & Unloading = Project Efficiency
- Divert drainage
- Establish a good, level grade
  - Use fine to medium material
  - Leveling course should be 3" (min)

Installation Keys

1-Handling

2-Dewatering

3-Bedding

4-Placement

5-Joining

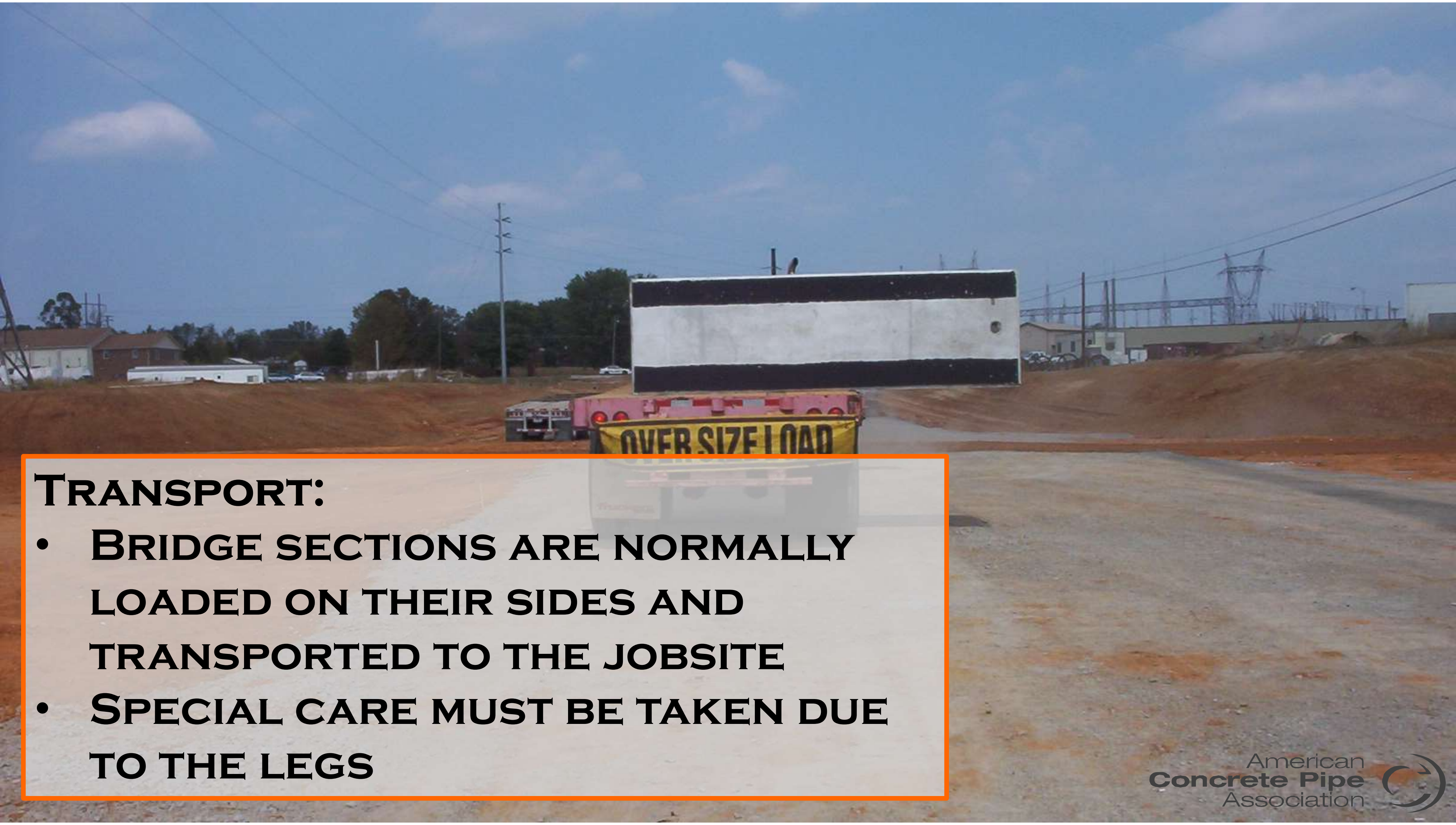
6-Final Backfill

7-End Treatments

8-Specials

1 - Handling

Handling:



Transport:

- Bridge sections are normally loaded on their sides and transported to the jobsite
- Special care must be taken due to the legs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OVERSIZE LOAD
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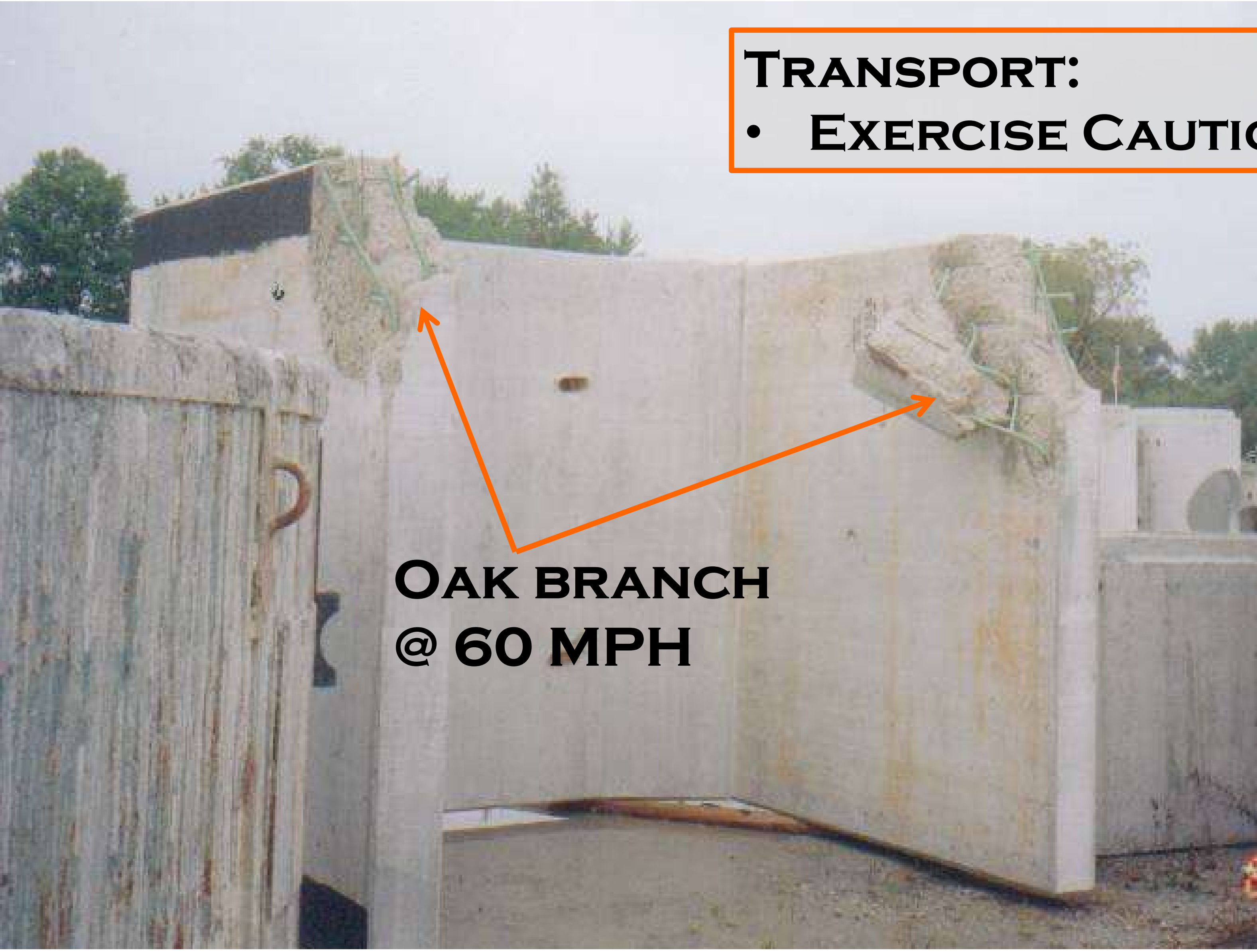
Transport:

- **Exercise Caution!**



2-Dewatering

Dewatering:

Control surface & ground Water

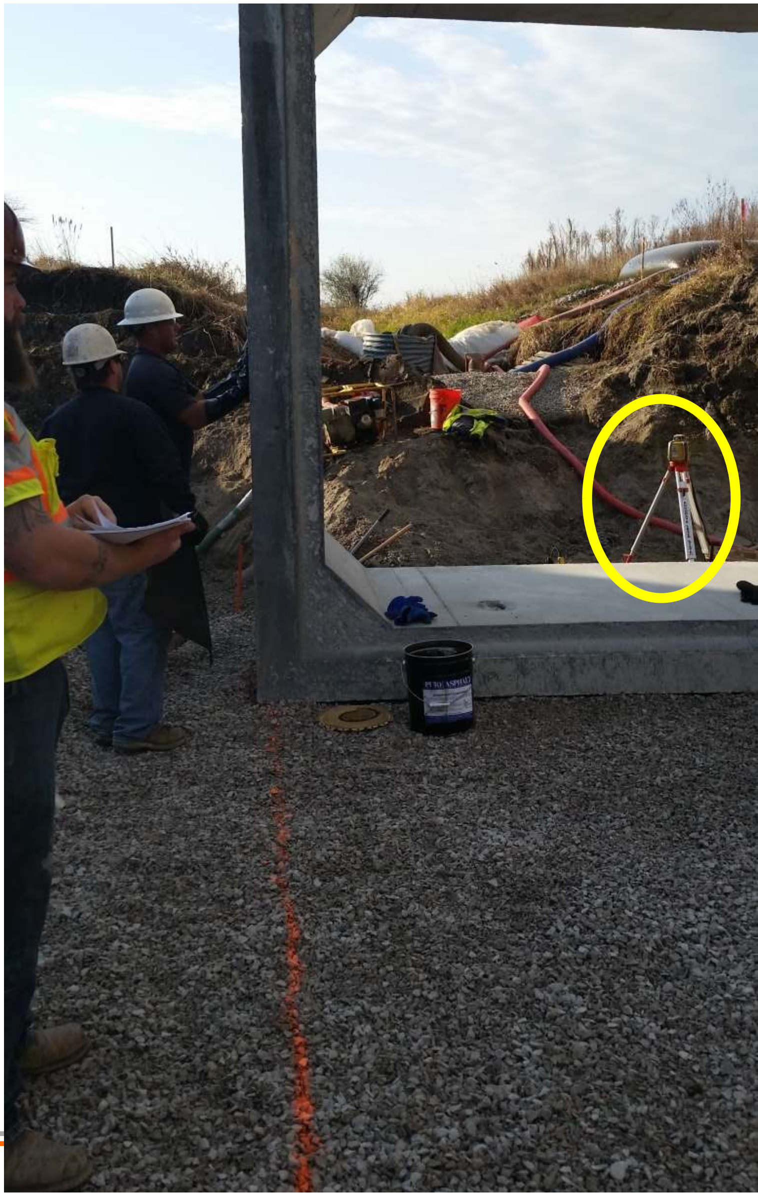
- Maintain dry conditions during installation

Dewatering:

3-Bedding

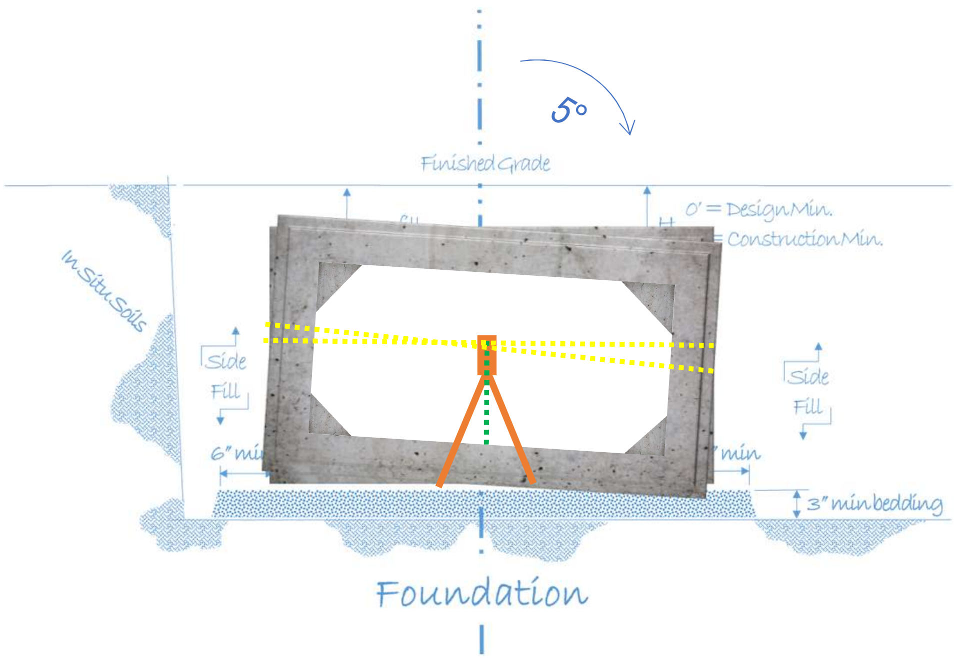
Bedding:

Check line and grade frequently and evenly

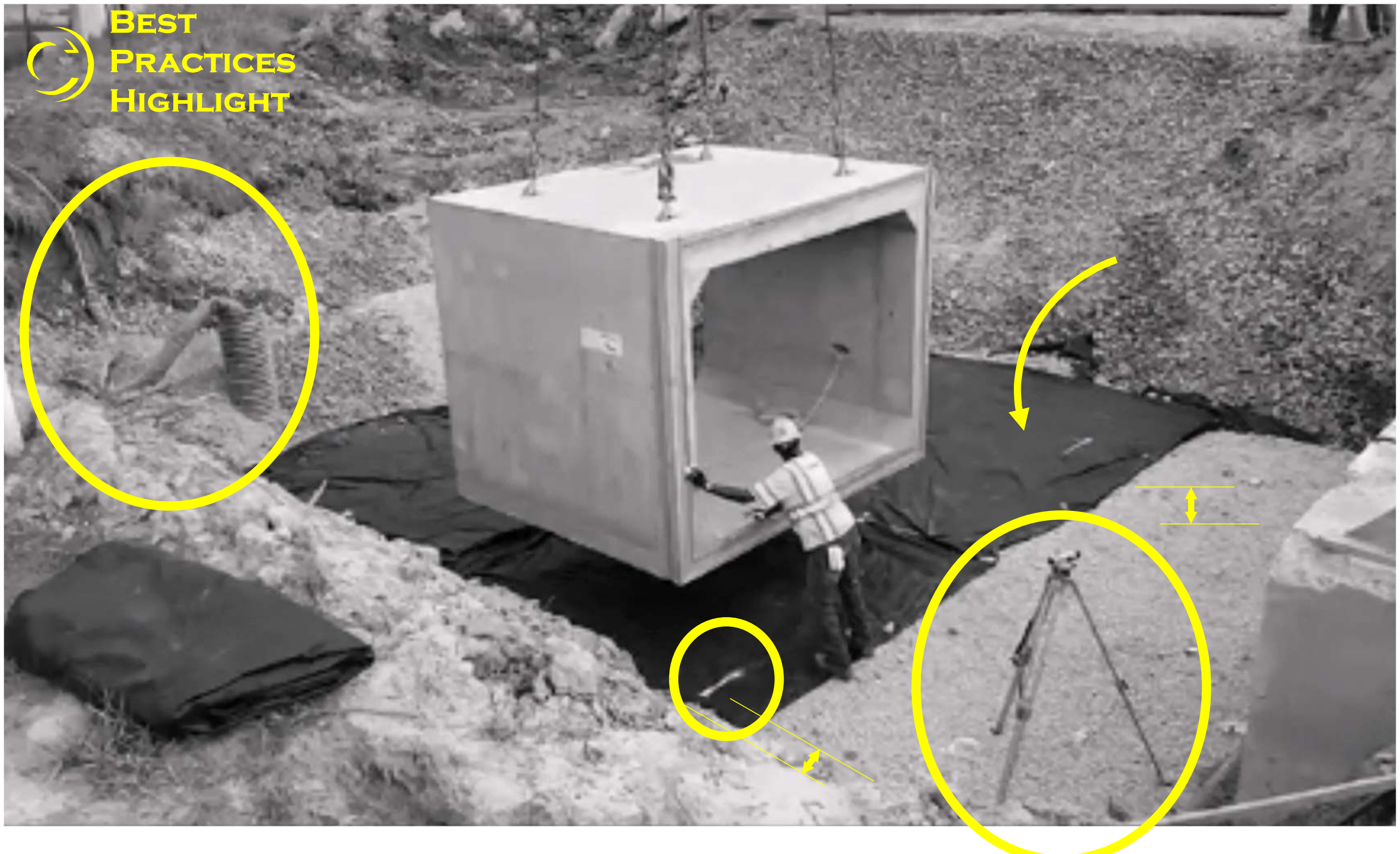


Bedding:

Check line and grade frequently and evenly



Bedding: Bedding is key to a smooth installation!



4-Placement

Placement:

Sequential marking helps proper placement on large/complex jobs

5-Joining

Joining:

ASTM C1577:

- Box joints are to be tongue & Groove
  - Mortar
  - Sealant
  - Fabric Wrap

Joining:

Various joint materials are used in the market:

- Mastic
- Neoprene Closed Cell Sponge
- Butyl Rubber Sealant
- Butyl Exterior Joint Wrap
- Profile Rubber Gaskets

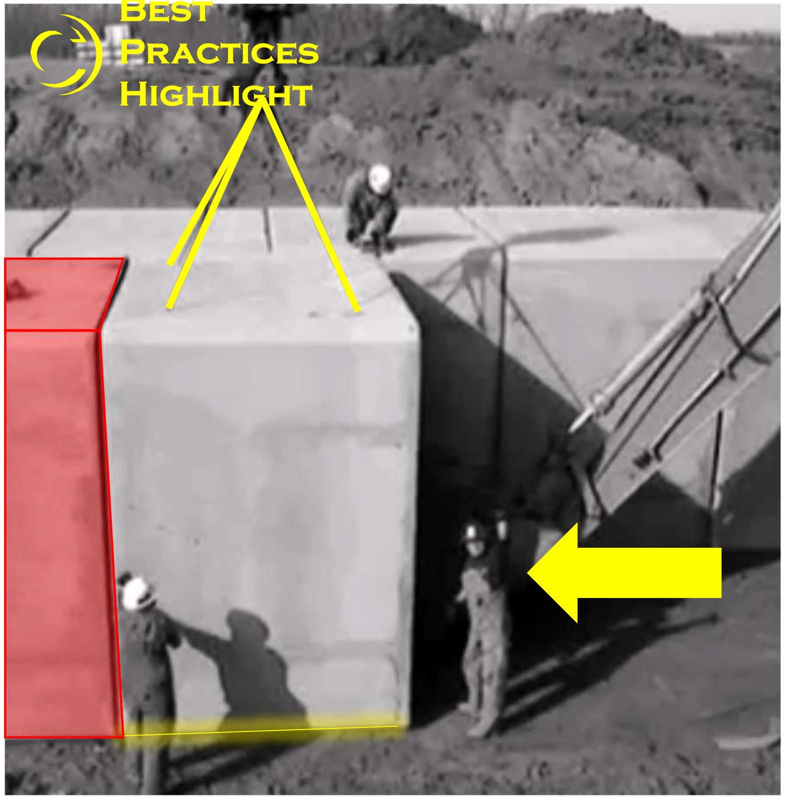



Joining:

- Prevent bedding material entering the joint.
- Smooth the bedding to improve homing the joint.

Joining:

Homing techniques driven by capabilities of crew, equipment & conditions.



Joining
Additional Options

- Pocket bolts
- Post tensioning strands

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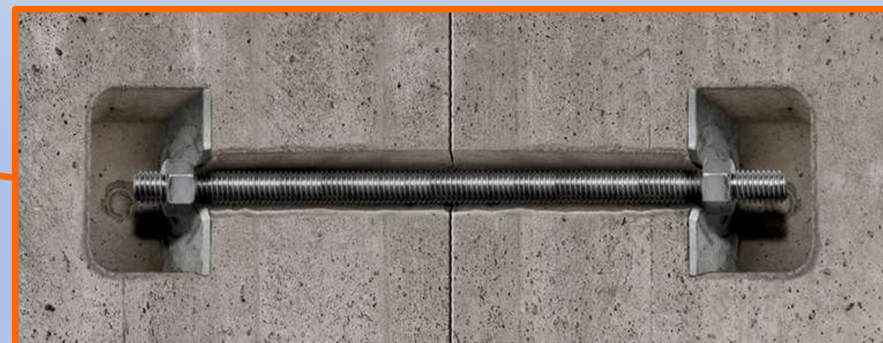
Joining
Additional Options



Pocket bolts

Joining
Additional Options

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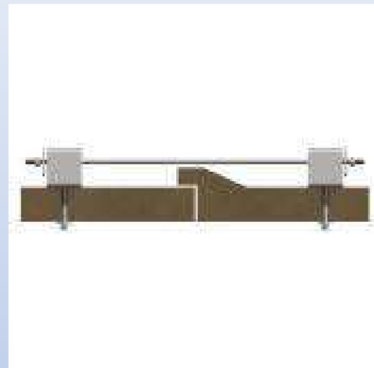

Joining
Additional Options

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Post tensioning strands

6-Final Backfill

Final Backfill:

- ❑ Compact backfill in lifts
- ❑ Avoid large rolling compactors over the culvert

- ❑ Avoid Construction loading with less than 3' of cover!

Final backfill: Minimum Cover

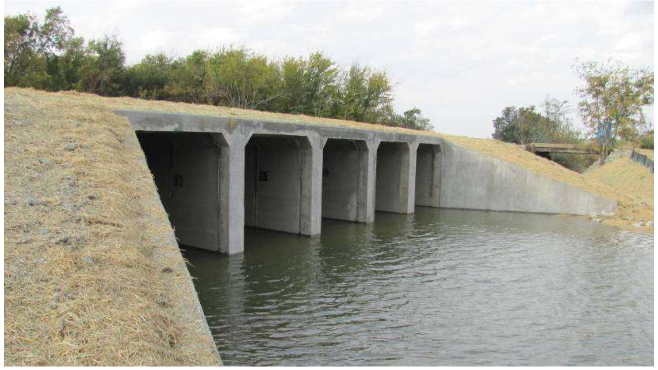
Provide wearing surface for minimum cover

Final backfill: maximum cover

Special design is needed for *DEEP* cover


KUBOTA

Successful 1st Installation:



7-End Treatments

End Treatments
PRECAST OPTIONS

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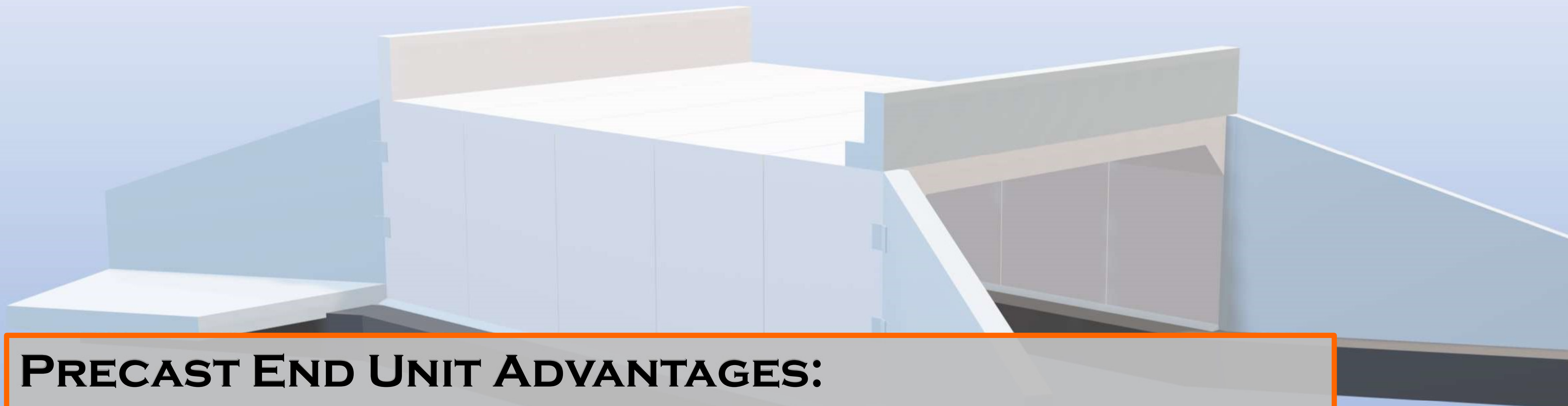

Precast End Unit Advantages:

- Save weeks off construction schedule
- Allows immediate backfill and cover
- Geometric flexibility—designed to fit your site
- Aesthetic molds are easily applied

End Treatments
PRECAST OPTIONS

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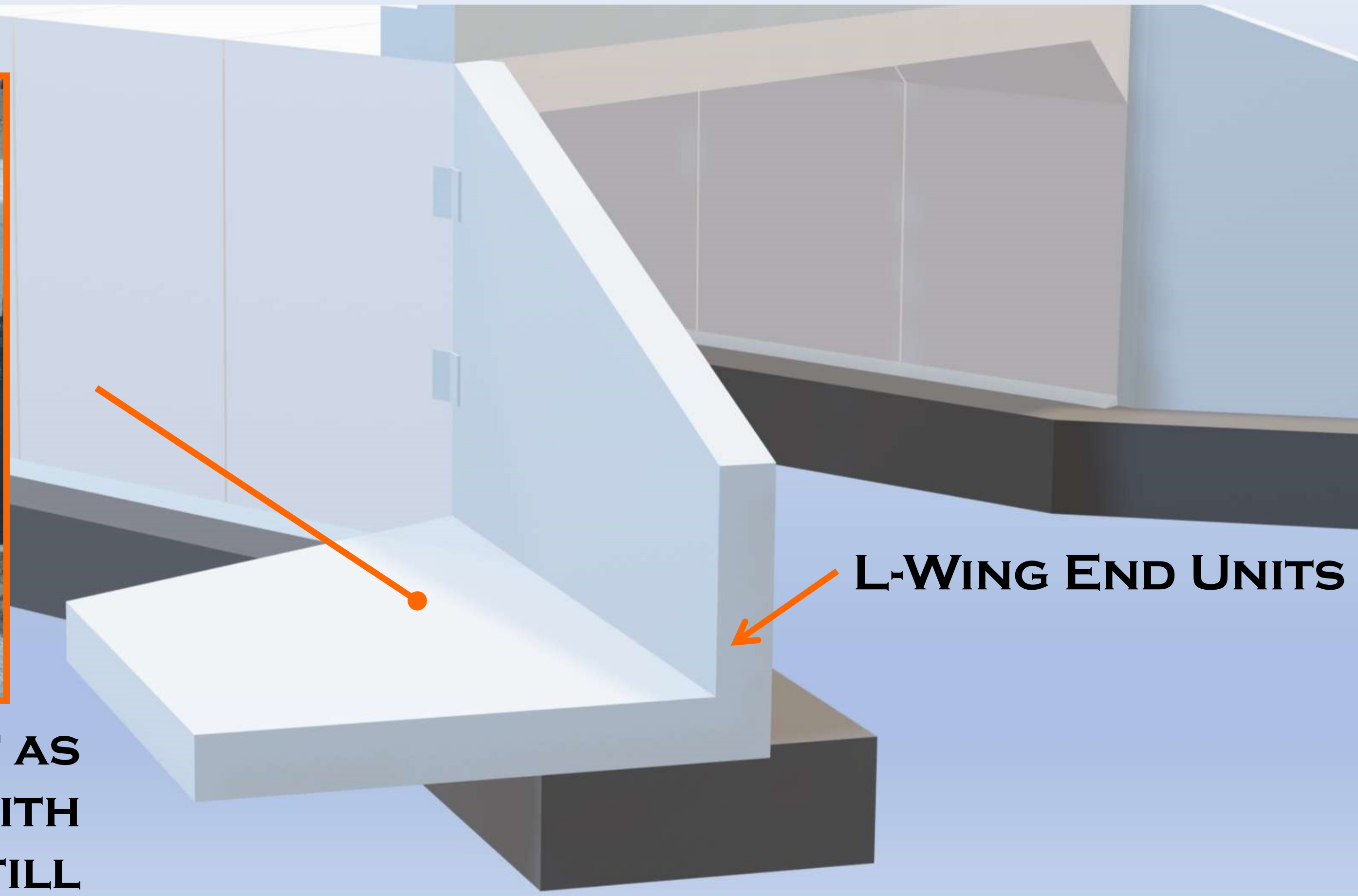
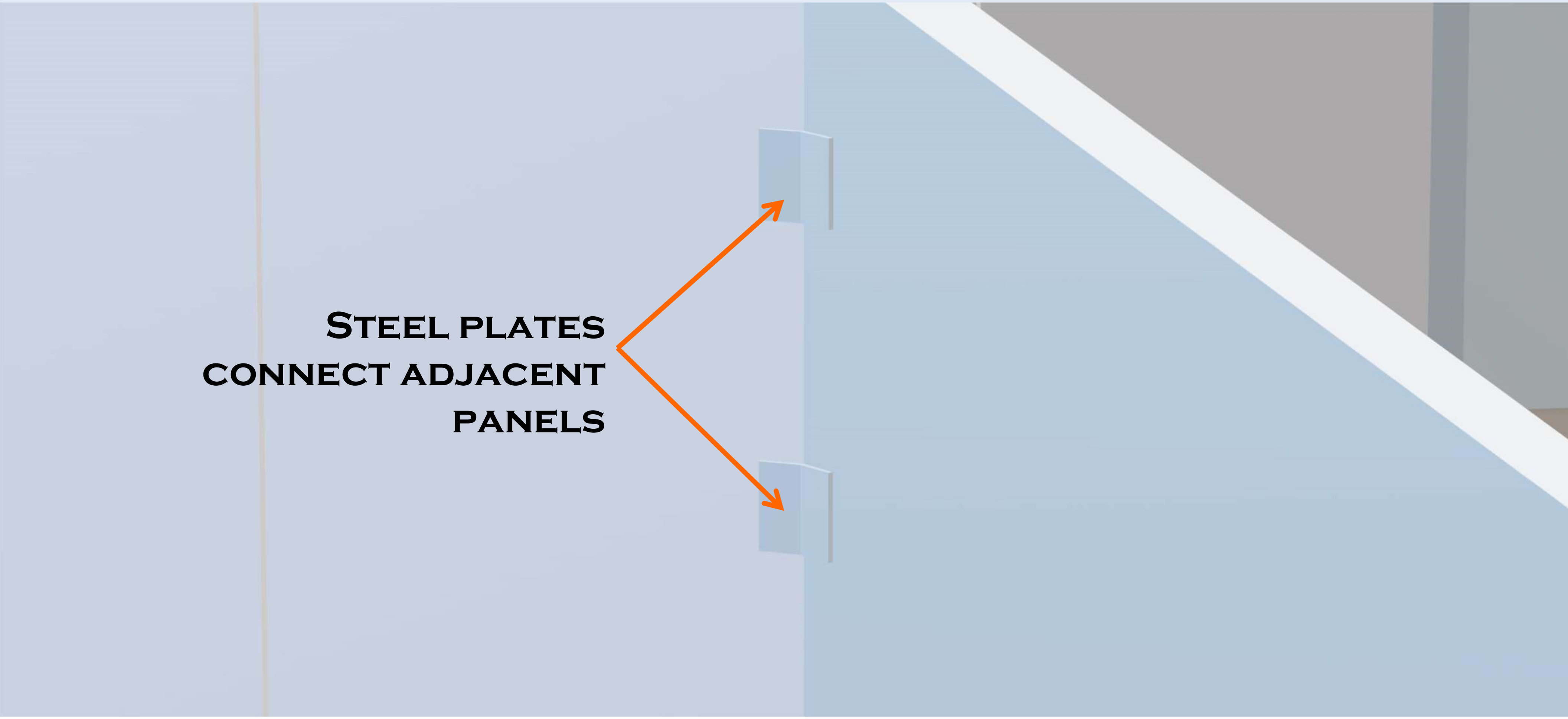


L-Wing Walls act as cantilevered walls with weight of soil backfill

End Treatments

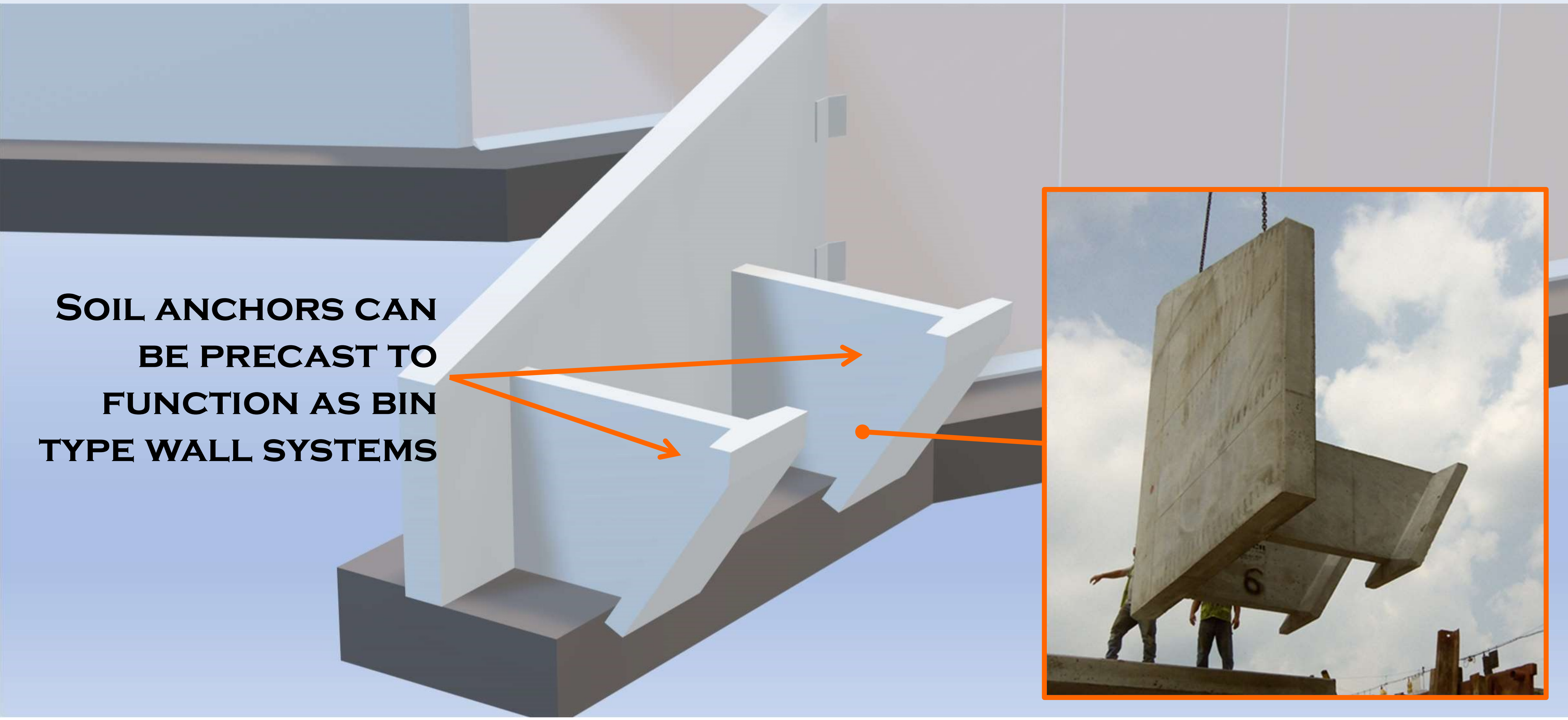
PRECAST OPTIONS



End Treatments

PRECAST OPTIONS

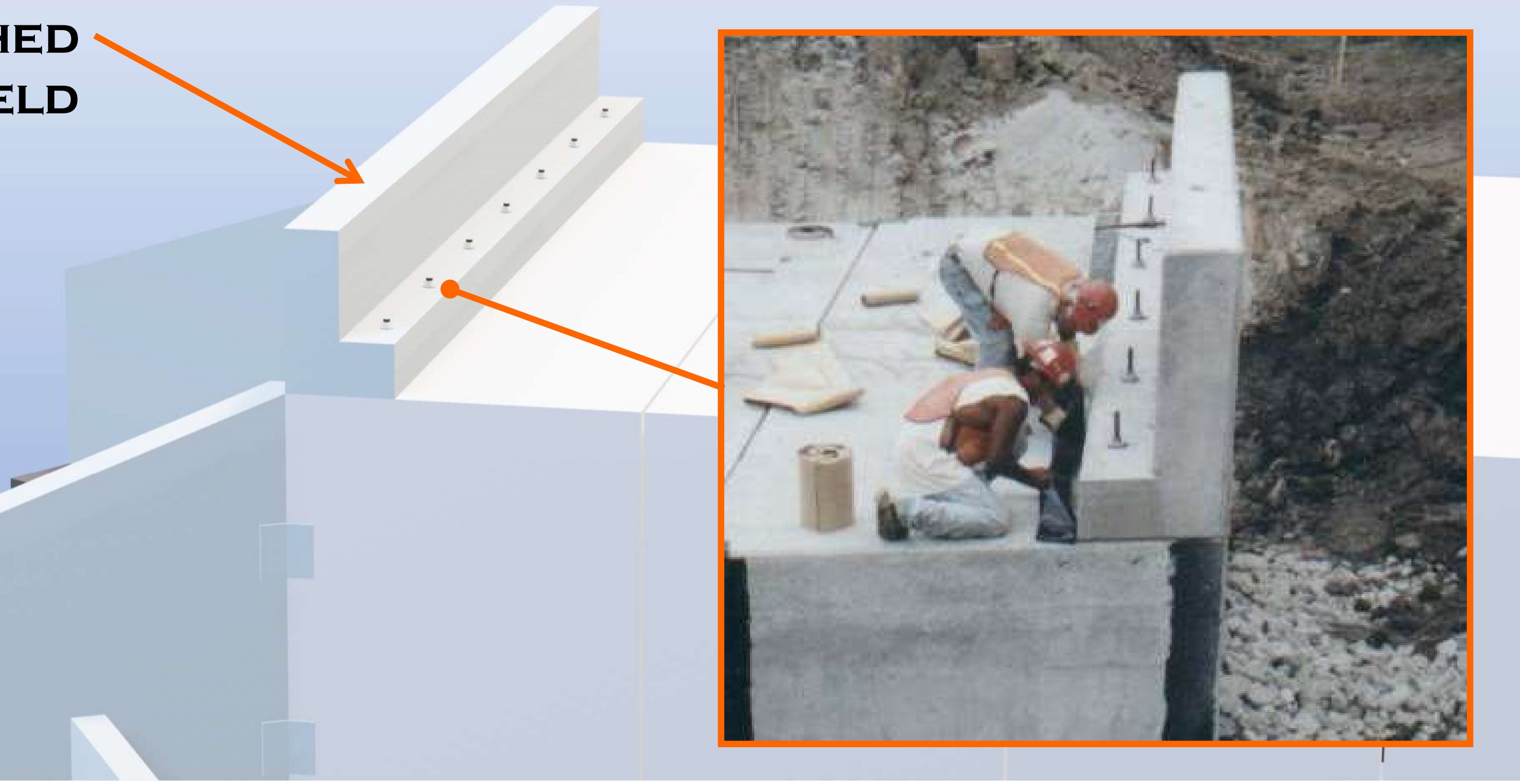
American Concrete Pipe Association



End Treatments
PRECAST OPTIONS

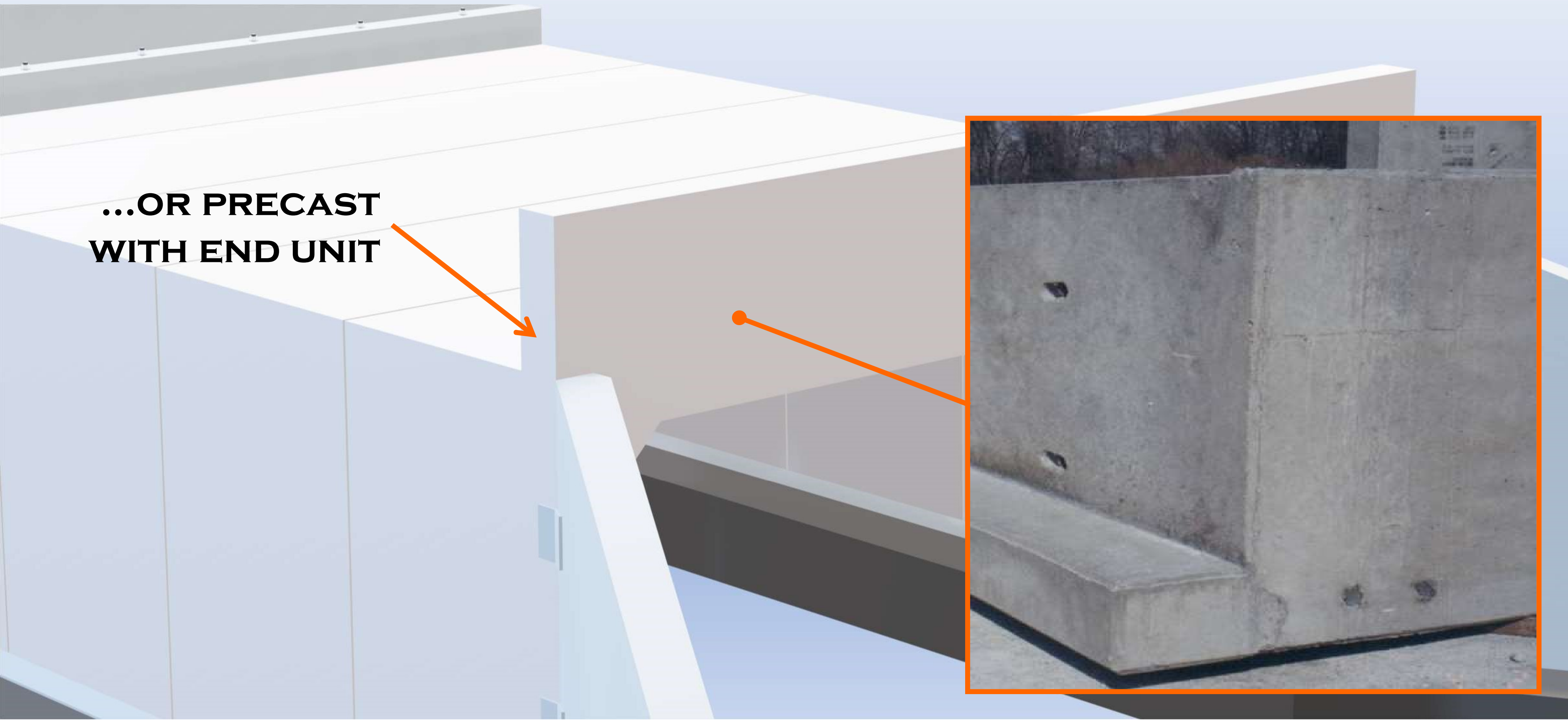
American Concrete Pipe Association

Headwalls can be precast & attached in the field



END TREATMENTS
PRECAST OPTIONS

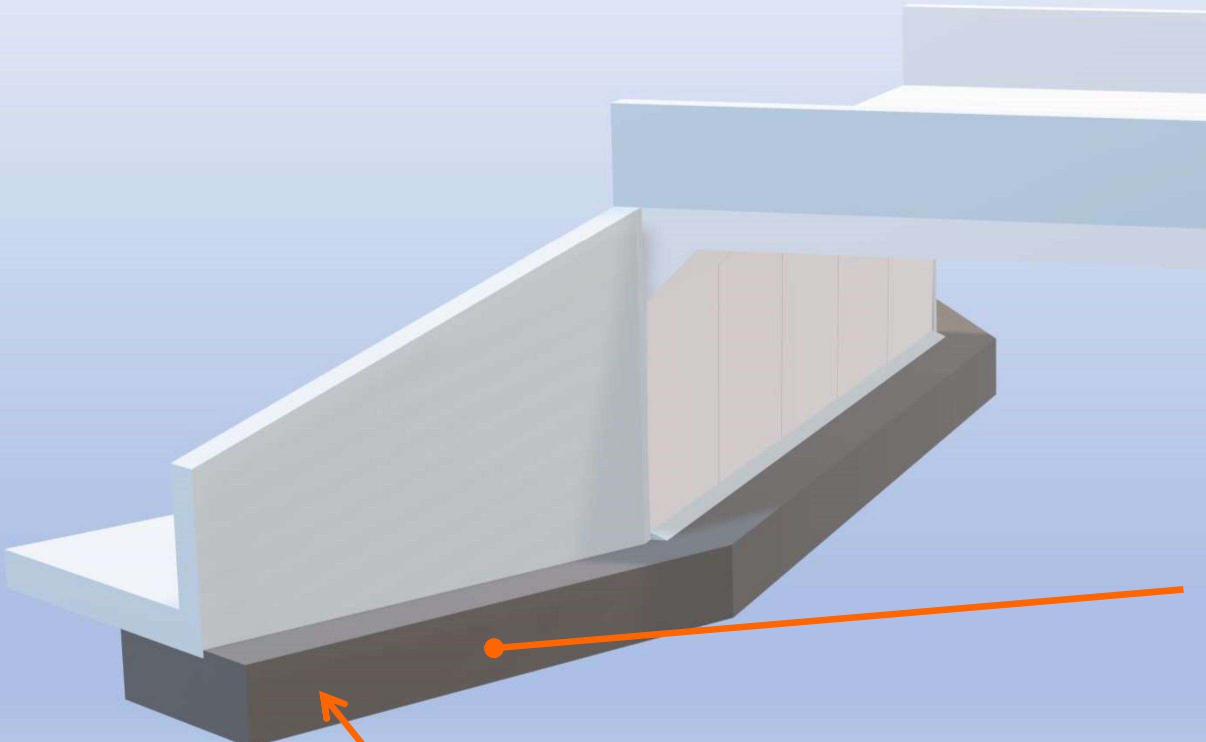
American Concrete Pipe Association



End Treatments
PRECAST OPTIONS

End Treatments
PRECAST OPTIONS

American Concrete Pipe Association



Strip footing continuous under flared wingwalls

End Treatments
PRECAST OPTIONS

American Concrete Pipe Association

Natural facades can be precast or cast in place into wingwalls & headwalls

End Treatments
PRECAST OPTIONS

End Treatments
PRECAST OPTIONS

8-Specials

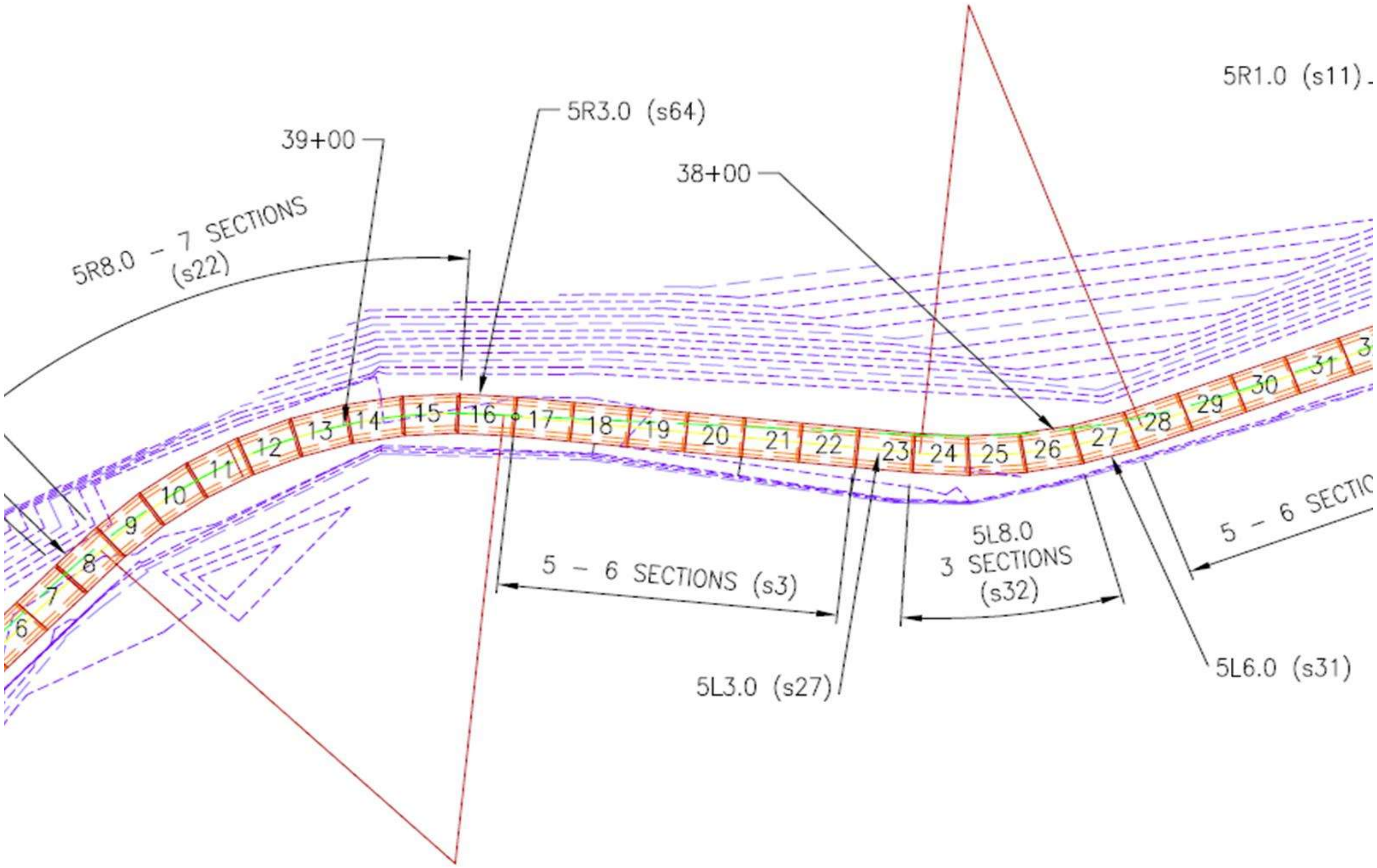
Specials:

Bends can save money & eliminate Junction boxes

Specials:

Manufacturers can customize any bend angle

Specials:



Logan Canyon:

- Lots of curves
- Winter hour construction (8 hours a day)
- No access road
- Transport up to 3,000 ft
- Leak Resistant Joints

Extending existing CIP Boxes

Multi Boxes:

Multicell vs Multibarrel

Skewed Ends:

Skews are limited by size & geometry.

Large Boxes:

Twin 14x11

23x8
Transition

20x12
Animal Crossing

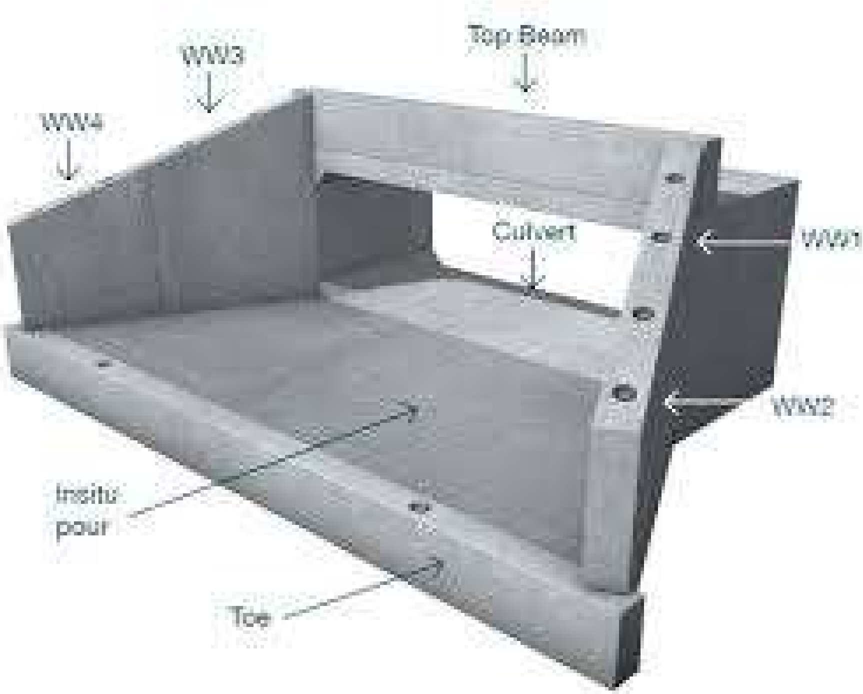
C1577: 3x2 → 12x12

Penetrations:

- Penetration addressed in plant
- Can be designed for field penetrations
- Top, bottom & side penetrations


RESILIENCE:
ADAPTIVE INFRASTRUCTURE

Resilience:



Resilience:

Adaptive Drainage infrastructure
Dry weather inverts


SOTP