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
Course Agenda

Precast Structures Fundamentals
Precast Structures
Fundamentals
Precast Structures: Fundamentals

Pipe
ASTM C76

4 Sided Box
ASTM C1577

3 Sided Box
ASTM C1504
Precast Structures:
Fundamentals

Pipe  4 Sided Box  3 Sided Box
ASTM C76  ASTM C1577  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: Fundamentals

Pipe 4 Sided Box 3 Sided Box
ASTM C96 ASTM C1577 ASTM C1564

Pipe Round Elliptical Arch

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

Precast Drainage Structures

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

Durable Reliable Infrastructure
Let’s Put on Our “Thinking Caps” about *applying today's lesson* to current or future jobs.
Much has been said about:

Think outside the box

Durable Reliable Infrastructure
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:

- **Standard, and Non-Std. uses**
- **Beyond Bridges and Culverts:**
  - 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!)*

Note: Box Culvert ≠ RCP²

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)
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 at 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
     - \( \text{headwater} / \text{diameter} \) ratio.
Hydraulic Modeling w/ HY-8—it’s free!

- Hydraulic computation Model for roadway stream crossings (Culverts)
- Created and Provided Online by FHWA:
- 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:

- 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.. **

Durable Reliable Infrastructure
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:
  - Design Flow Rate
  - Maximum Allowable Headwater Depth
  - Culvert Slope
  - Type of Culvert Material
  - Type of Inlet

Same as Inlet Control

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

- Live Load Distribution (H<2'; H>2')
- Modifications of earth loads for soil structure interaction
- Distribution of concentrated loads to bottom slab of box culvert
- Service limit states (High comp. thrust forces \(\rightarrow\) reduces stresses)
- Design moment
- Minimum reinforcement
- Minimum top slab concrete cover

Durable Reliable Infrastructure
BOXCAR Software or ET Culvert

- AASHTO / ASTM C1577 design
- 3D wireframe generation
- Load ratings per C1577 & Section 12

Durable Reliable Infrastructure
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:

<table>
<thead>
<tr>
<th>Design Earth Cover, ft</th>
<th>Circumferential Reinforcement Areas, in.²/ft</th>
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<td>0.18</td>
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<td>30</td>
<td>0.17</td>
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</tbody>
</table>

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)

Durable Reliable Infrastructure
Cover: 0-2'

AASHTO: M273
ASTM: C850

ASTM: C1433
LRFD → ASTM: C1577

Cover: 2’+

AASHTO M259
ASTM C789
Minimum Cover

0’ cover:
- Maximizes hydraulic capacity
- Place road surface directly over boxes

Durable Reliable Infrastructure
Installation Options

- Jacked
- Trench
- Embankment
**ASTM C1675**

- **Foundation:**
  - 6" min bedding/leveling course
  - Overfill
  - Finished Grade
  - Span
  - Rise

- **Trench:**
  - 6" min bedding/leveling course
  - Side Fill
  - In situ soils

- **Embankment:**
  - 6" min bedding/leveling course
  - Side Fill

**Best Practice:**
- 6" medium granular material foundation compacted

0' = Design Min.
3' = Construction Min.
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

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>1</strong>-Handling</td>
<td><strong>2</strong>-Dewatering</td>
<td><strong>3</strong>-Bedding</td>
<td><strong>4</strong>-Placement</td>
</tr>
<tr>
<td><strong>5</strong>-Joining</td>
<td><strong>6</strong>-Final Backfill</td>
<td><strong>7</strong>-End Treatments</td>
<td><strong>8</strong>-Specials</td>
</tr>
</tbody>
</table>
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**
Transport:
• Exercise Caution!

Oak branch @ 60 MPH
2-Dewatering
Dewatering:
Control surface & ground Water

- Maintain dry conditions during installation
Dewatering:

Exception TO THE RULE
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
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
JOINING
ADDITIONAL OPTIONS

Pocket bolts
JOINING
ADDITIONAL OPTIONS
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
Successful 1st Installation:
7-End Treatments
End Treatments
Precast Options

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**
L-Wing Walls act as cantilevered walls with weight of soil backfill.
END TREATMENTS
PRECAST OPTIONS

Steel plates connect adjacent panels.
Soil anchors can be precast to function as bin type wall systems.
End Treatments
PreCast Options

Headwalls can be precast & attached in the field.
End Treatments
Precast Options

...or precast with end unit
End Treatments
Precast Options

Strip footing continuous under flared wingwalls
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
THANK YOU FOR YOUR TIME.