Seventeenth Statewide Conference on Local Bridges
Tuesday, October 25, 2011

Training Session: Culvert Design, Analysis - talk 3
Presented by:
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NYSDOT

LRFD SPECIFICATIONS for BURIED STRUCTURES
Live Load Distribution

October 25, 2011

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Department of Transportation
State of New York

Buried Structure:
A generic term for a structure built by embankment or trench methods.

Tunnel:
A horizontal or near horizontal opening in soil excavated to predesigned geometry by tunneling methods exclusive of cut-and-cover methods.

Materials:
Aluminum, Cast-In-Place Concrete & Precast Concrete, Steel, Thermoplastic Pipe

LRFD Section 12
BURIED STRUCTURES AND TUNNEL LINERS

- Metal Pipes / Structural Plate Pipe / Structure Plate Box
- Reinforced Concrete Pipe
- Reinforced Concrete Cast-In-Place & Precast Arch, Box, Elliptical
- Thermoplastic Pipe
**Limit State & Resistance Factors**

\[ R_r = \Phi R_n ; \sum \eta_i \gamma_i Q_i \leq \Phi R_n = R_r \]

- \( R_r \) – Factored Resistance
- \( R_n \) – Nominal Resistance
- \( \Phi \) – Resistance Factor (Table 12.5.5.1)
- \( \gamma \) – Load Factor ; \( Q \) – Force Effect

<table>
<thead>
<tr>
<th>Table 12.5.5.1 (( \Phi ) Value)</th>
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<td><strong>Flexure</strong></td>
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<td>C.I.P. Box Structures</td>
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<tr>
<td>Precast Box</td>
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<tr>
<td>Precast 3-sided Structure</td>
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**Service Limit State** *(Table 3.4.1-1)*

- Deflection
- Crack Width in Reinforced Concrete Structures

**Strength Limit State** *(Table 3.4.1-1)*

- Load Combinations I & II

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**Section 12.6**

**General Design Features**

**Loading**
- Horizontal & Vertical Earth Pressure
- Pavement Load
- Live Load
- Earth Surcharge, LL Surcharge, Downdrag Loads
- External Hydrostatic Pressure / Water Buoyancy Loads
- Earthquake Loads, Uplift, Minimum Soil Cover

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**Section 12.11**

- Precast Box Culverts
- Reinforced Cast-in-place Box Culverts
- Reinforced Cast-in-place Arches

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**Section 12.14**

- Precast Reinforced Concrete Three-Sided Structures
Section 12.11 (Box Culverts)
12.11.2.1 – Top Slab LL Distribution

<table>
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<td>4.6.2,10</td>
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<td>D_f ≥ 2.0 feet</td>
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<td>IM (Dynamic Load allowance)</td>
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Section 12.14 (3-Sided Units)
12.14.5 - Design

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<td>4.6.2,10.4 &amp; 12.4.5.4 additional requirements</td>
<td></td>
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<tr>
<td>Deflection Control at the Service Limit State 12.14.5.9</td>
<td>2.5.2,6,2 Provisions are mandatory</td>
<td></td>
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Live Load
3.6.1.2 Design Vehicular LL

- Design Truck or Design Tandem
- Design Lane Load
  - Each design lane (either design truck or tandem + lane load)
  - The loads assumed to occupy 10.0’ transversely within a design lane

3.6.1.2.5 Tire Contact Area (Wheel; 1 or 2 tires)

TRAFFIC DIR.   W   L=10”   W=20”

For D_f (Fill Depth) ≥ 2.0’

Distributed Rectangular Area =

\[
[ L+(1.15 \text{ or } 1.0) \times D_f ] \times [ W+(1.15 \text{ or } 1.0) \times D_f ]
\]

Factor 1.15 for Select Granular Backfill & 1.0 for fill in all other cases

3.6.1.1.2 - Multiple Presence Factor
3.6.2.2 - Dynamic Load Allowance

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3.6.1.2.6 Distribution of Wheel Load Through Earth Fills

For $D_f$ (Fill Depth) ≥ 2.0'

- Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.
- For single-span culverts, LL may be neglected where $D_f > 8.0'$ and exceeds span length.

For $D_f$ (Fill Depth) < 2.0'

Article 4.6.2.10

( $D_f < 2.0'$ )

4.6.2.10 – Equivalent Strip Widths for Box Culverts

4.6.2.10.2 – Case 1: Traffic Travels Parallel to Span

- Single Loaded Lane with Single Lane MPF

[When traffic travels parallel to span, culverts shall be analyzed for a single loaded lane with the single lane Multiple Presence Factor, MPF=1.2 for Single Lane]

- The axle load shall be distributed to top slab for determining moment, thrust & shear.
- $E_{span}$ (Increased load width parallel to span) may be conservatively neglected in design and may be taken as a point load - Past Practice.
4.6.2.10.2 – Case 1: Traffic Travels Parallel to Span

(\(D_t < 2.0\) ‘)

In decks, we can have

Primary Span Strip
derpendicular to Direction
of Traffic

4.6.2.10.3 – Case 2: Traffic Travels Perpendicular to Span

(\(D_t < 2.0\) ‘)

E – Axle Load Distribution Width

\[E = 26.0 + 6.6 \times S \quad (+M)\]

\[E = 48.0 + 3.0 \times S \quad (-M)\]

In this case, culverts can have two or more trucks on the same design strip at the same time. This effect is to be considered along with M.P.F. (Multiple Presence Factor)
3.6.1.3 – Application of Vehicular Live Loads

3.6.1.3.3 – Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts

**Top Slabs of Box Culverts**
- Only the axle loads of the design truck or tandem shall be applied (Design lane load does not need to be considered)

**Deck Systems (Span ≤ 15 ′)**
- Only the axle loads of the design truck or tandem shall be applied (Design lane load does not need to be considered)

**Deck Systems (Span > 15 ′)**
- Design lane load along with design truck or tandem to be considered
4.6.2.10.2 – Case 1: Traffic Parallel to Span (0° Skew)

- We have adopted this case for skews up to and including 15° and have modified LRFD Specifications with NYS Blue Pages for both Box Culverts and 3-Sided Units

**Skew Effect**

\[ D_f < 2.0', \text{ (Section 4.6.2.10)} \]

<table>
<thead>
<tr>
<th>Span (Feet)</th>
<th>( n ) (No of Lanes) &amp; Total Load</th>
<th>( E ) (Traffic Parallel) (0° skew)</th>
<th>( E ) (Traffic Normal) (90° skew)</th>
<th>Load / E (1.2W / E) (0° skew)</th>
<th>Load / E (mpf*TL/E) (90° skew)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1W</td>
<td>8.26</td>
<td>5.25</td>
<td>0.145W</td>
<td>0.229W</td>
</tr>
<tr>
<td>10</td>
<td>1W</td>
<td>9.2</td>
<td>6.5</td>
<td>0.130W</td>
<td>0.185W</td>
</tr>
<tr>
<td>15</td>
<td>1W</td>
<td>9.8</td>
<td>7.75</td>
<td>0.122W</td>
<td>0.155W</td>
</tr>
<tr>
<td>20</td>
<td>1W</td>
<td>10.4</td>
<td>9</td>
<td>0.115W</td>
<td>0.133W</td>
</tr>
<tr>
<td>25</td>
<td>1W ; 2W</td>
<td>11.0</td>
<td>10.25</td>
<td>0.109W</td>
<td>0.195W</td>
</tr>
<tr>
<td>30</td>
<td>1W ; 2W</td>
<td>11.6</td>
<td>11.5</td>
<td>0.103W</td>
<td>0.174W</td>
</tr>
<tr>
<td>35</td>
<td>1W ; 2W</td>
<td>12.2</td>
<td>12.75</td>
<td>0.098W</td>
<td>0.157W</td>
</tr>
<tr>
<td>40</td>
<td>1W ; 3W</td>
<td>12.8</td>
<td>14</td>
<td>0.094W</td>
<td>0.182W</td>
</tr>
<tr>
<td>45</td>
<td>1W ; 3W</td>
<td>13.4</td>
<td>15.25</td>
<td>0.090W</td>
<td>0.167W</td>
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</table>

4.6.2.10.3 – Case 2: Traffic Perpendicular to Span (90° Skew, 4.6.2.1 – Decks Case)

LRFD Code Commentary states that this approximate strip model for decks is based on rectangular layout. **SKEW TENDS TO DECREASE FORCE EFFECTS PRODUCED FROM THIS CASE.**

- We verified this clause also.

Box Culverts (12.11)

- 12.11.2.4 - Wheel distribution specified for top slabs need not be corrected for side walls & bottom slab

Three-Sided Structures (12.14)

- 12.14.5.3 - Wheel loads on skewed culverts to follow same provisions as for culverts with main reinforcement parallel to traffic
- For skew angle > 15°, the effect of skew to be considered

[State of New York Department of Transportation]
Skew Effect

4.6.2.10.3 – Case 2: Traffic Perpendicular to Span
(90° Skew, 4.6.2.1 – Decks Case)

- We have adopted this case for all skews > 15° and have modified LRFD Specifications with NYS Blue Pages for both Box Culverts and Three-Sided Units.

BLUE PAGE 12.14.5.3

12.14 PRECAST REINFORCED CONCRETE THREE-SIDED STRUCTURES
12.14.5 Design
12.14.5.3 Distribution of Concentrated Loads in Skewed Culverts

Delete the last sentence of the first paragraph and replace it with the following sentence:

For culvert elements with skews greater than 15 degrees, the effect of skew shall be considered in the analysis using the provisions as given for culverts with main reinforcement perpendicular to traffic.

Traffic traveling perpendicular to the span can have two or more trucks on the same lane strip at the same time. This along with multiple presence shall be accounted for in design. For the Strength II limit state only one lane loaded with multiple presence shall be considered.

BLUE PAGE 12.11.2.1

12.11 REINFORCED CONCRETE CAST-IN-PLACE AND PRECAST BOX CULVERTS AND REINFORCED CAST IN PLACED ARCHES
12.11.2 Loads and Live Load Distribution
12.11.2.1 General

Add the following at the end of the first paragraph:

For wheel loads on box culverts skewed 15 degrees or less the effect of skew may be neglected by using the provisions as given for culverts with main reinforcement parallel to traffic. For box culverts with skews greater than 15 degrees, the effect of skew shall be considered in the analysis using the provisions as given for culverts with main reinforcement perpendicular to traffic.

Traffic traveling perpendicular to the span can have two or more trucks on the same design strip at the same time. This along with multiple presence shall be accounted for in design. For the Strength II limit state only one lane loaded with multiple presence shall be considered.
**Section 12.11 (Box Culverts)**

**LL Distribution**

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**Section 12.14 (3-Sided Units)**

**LL Distribution**

<table>
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<th>Same as Top Slab (Box Culverts) 12.11.2.1</th>
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<tr>
<td>Skew 12.14.5.3</td>
<td>&gt; 15°; Effect of Skew shall be considered in analysis</td>
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### Shear Transfer in Transverse Joints / Edge Beams

**4.6.2.10.4 (12.11.2.1) – Precast Box Culverts**

- Span / Thickness (s/t) ≤ 18 & Segment Length ≥ 4'
  - Shear Transfer across the joints need not be provided

- If above requirements are not satisfied
  - Provide the culvert with a means of shear transfer between adjacent sections. Shear transfer may be provided by pavement, soil fill or physical connection.
  - Design the Section Ends as Edge Beam (4.6.2.1.4)

**12.11.2.2 – Modification of Earth Loads (DL)**

**Embankment Condition:**

\[ W_E = F_e \gamma_s B_c H \quad (12.11.2.2.1-1) \]

\[ F_e = 1 + 0.20 \times H / B_c \quad (12.11.2.2.1-2) \]

**Trench Condition:**

\[ W_E = F_t \gamma_s B_c H \quad (12.11.2.2.1-3) \]

\[ F_t = \left( \frac{C_d B_d^2}{H B_c} \right) \leq F_e \quad (12.11.2.2.1-4) \]

### Shear Transfer in Transverse Joints

**12.14.5.4 – Precast Reinforced Concrete 3-Sided Structures**

- 4.6.2.10.4 Provisions shall apply (for Box Culverts)

- Additionally, shear transfer to be provided in top slabs for \( D_f < 2.0' \) & subjected to vehicular LL unless
  \[ t \quad (\text{slab thickness}) \geq (S+10) / 30 \]

These requirements are for Flat Top Structures and do not apply to Arch-Top Structures.
**QUESTIONS FOR PDF**

1. In general for the design of buried structures, what load combinations for Strength Limit State Design are considered?

2. As per code for the design of buried structures, when do we consider earthquake loads?

3. In LRFD Specifications, what magnitude of ‘Fill Depth’ differentiates the Live Load Distribution Criteria for culverts?

4. In LRFD Specifications to incorporate skew effects, what magnitudes of skew angles are to be considered in analysis?

5. For a no skew case or when traffic travels parallel to span, what case of Live Load is to be analyzed for culverts?
   - (a) Single Lane Load with MPF or
   - (b) Multiple Lanes that can be accommodated on the culvert?

6. What portion of Live Load (Design Truck, Design Tandem or Design Lane) is to be applied for box culverts?