Illinois Department of Transportation
Memorandum

To:	ALL BRIDGE DESIGNERS	11.3 (REV)
From:	D. Carl Puzey	
Subject:	LRFD Design Requirements for Precast and Cast-In-Place Concrete Box Culverts	
Date:	November 2, 2011 (Revised January 27, 2012)	

The Department is beginning implementation of AASHTO Load and Resistance Factor Design (LRFD) for buried structures, which includes culverts, pipes and three sided structures. This memorandum addresses concrete box culverts.

PRECAST CONCRETE BOX CULVERTS

Effective with the 2012 Standard Specifications for Road and Bridge Construction and beginning with the January 20, 2012 letting, all precast concrete box culverts and precast extensions of existing culverts shall utilize LRFD by applying the standard designs of ASTM C 1577. Precast box configurations and loadings not addressed in ASTM C 1577 may be designed utilizing LRFD with the latest version of the BOXCAR program, provided similar slab and wall thicknesses of the nearest standard geometric configurations from ASTM C 1577 are used. These non-standard precast box culvert sections shall have the design shown on the contract plans, similar to a cast-in-place box, and shall be sealed by an Illinois Licensed Structural Engineer. The following table is a list of standard precast box configurations that may be found in ASTM C 1577. Standard configurations are encouraged for new culvert designs. If the closest standard configuration is too tall for a specific application, consider setting the box invert deeper or utilizing more culvert barrels of a shallower configuration before using a non-standard configuration.

Standard Precast Concrete Box Culvert Configurations (Span x Rise - ft.)				
3 x 2	6 x 3	8 x 4	9 x 9	11 x 6
3 x 3	6 x 4	8 x 5		11 x 8
	6 x 5	8 x 6	10 x 5	11 x 10
4 x 2	6 x 6	8 x 7	10 x 6	11 x 11
4 x 3		8 x 8	10 x 7	
4 x 4	7 x 4		10 x 8	12 x 4
	7 x 5	9 x 5	10 x 9	12 x 6
5 x 3	7 x 6	9 x 6	10 x 10	12 x 8
5 x 4	7 x 7	9 x 7		12 x 10
5 x 5		9 x 8	11 x 4	12 x 12

It is important to note there are a few design limitations associated with ASTM C 1577. First, the design tables are adequate for skews up through 30 degrees and also for larger skews when the design fill is greater than 5 feet. Skews larger than 30 degrees with design fills less than or equal to 5 feet shall be handled with design tables that IDOT will provide through a (BDE) special provision entitled

"CONCRETE BOX CULVERTS WITH SKEWS > 30 DEGREES AND DESIGN FILLS ≤ 5 FEET (BDE)" prior to the January letting. Designs from this special provision or ASTM C 1577 do not require a seal by an Illinois Licensed Structural Engineer. This policy is summarized in the following chart.

Skew*	Design Fill	Specification
≤ 30	All Fills	ASTM C 1577
> 30	> 5 ft	ASTM C 1577
> 30	≤ 5 ft'	IDOT Special Provision

*The skew is the angle between a perpendicular line to the box culvert and the centerline of the roadway.

Second, the design tables of ASTM C 1577 are based on a live load distribution of 1.15 in both directions through design fills ≥ 2 feet. To achieve this distribution, Porous Granular Embankment (PGE) backfill is required for all boxes meeting either of the following two conditions:

- Depth of fill ≥ 2 ft. and ≤ 8 ft.
- Depth of fill ≤ span of largest box in configuration

The limits and quantities of the PGE necessary for the box installation shall be shown and included in the roadway plans.

Design fills less than 2 feet shall satisfy the requirements of AASHTO LRFD Article 4.6.2.10. The Department recommends PGE or a continuation of the roadway sub base up to the 2 feet of fill. Note that for Case 1, parallel to the span, the LLDF shall then be 1.15.

Roadway Plan Presentation

Over the years, many Districts have developed their own unique contract plan details for precast box culverts, some by repeating portions of the AASHTO details and tables and others by developing their own notes, tables and details. This transition from Load Factor Design (LFD) to LRFD design is a good opportunity to unify and promote consistent details throughout the State. Therefore, in lieu of the various past practices, we are recommending the following:

1. Each culvert shall be identified on the plan/profile sheets of roadway plans with the following information:

   ASTM C 1577; Station; Size; Skew; Design Fill

   Fabricators will be instructed in the Bureau of Materials and Physical Research (BMPR) policy memorandum "Quality Control/ Quality Assurance Program for Precast Concrete Products" to identify each precast box culvert section in the same way for easy identification and location in the field. Additionally, the policy memorandum requires fabricators to include their producer mark and the date of manufacture on each precast box culvert section.

2. Each set of applicable roadway plans shall have a Culvert Schedule including the following minimum information. The designer shall determine the design fill heights, and shall note whether PGE backfill is required.

Precast Box Culvert Schedule (ASTM C 1577)					
Station	Size (Span x Height)	Skew*	Design Fill (ft.)		PGE backfill required
			Edge of shldr. (minimum)	Maximum	

*Skews > 30° with design fills ≤ 5 ft. require a special design. See BDE Special Provision "CONCRETE BOX CULVERTS WITH SKEWS > 30 DEGREES AND DESIGN FILLS ≤ 5 FEET (BDE)". The skew is the angle between a perpendicular line to the box culvert and the centerline of the roadway.

3. The roadway plans shall clearly illustrate the intended limits, pay item and quantity of the PGE necessary for the box installation.

CAST-IN-PLACE (CIP) BOX CULVERTS

In order to allow some time for plan preparation, all CIP concrete box culverts and CIP extensions of existing culverts, beginning with the June 15, 2012 letting and beyond shall utilize LRFD according to the latest version and interims of the AASHTO LRFD Bridge Design Specifications. The Department anticipates issuing Standardized Design Tables of single span box culverts for the Culvert Manual. Until these tables become available, all CIP simple span box culverts, on the June 15, 2012 letting and beyond, will require a design sealed by an Illinois Licensed Structural Engineer. All multi-span CIP boxes will continue to require a design sealed by an Illinois Licensed Structural Engineer similar to our current policy.

Design Preferences

The same live load distribution of 1.15, as previously discussed for precast concrete box culverts, shall also be used for CIP boxes. As such, PGE will also be required for the same ranges of design fill.

CIP concrete box culverts shall be designed for the perpendicular span between the culvert walls. The main flexure reinforcement is therefore also placed at right angles to the wall. On skewed structures, the skewed areas near staged construction lines or end sections shall preferably be addressed with an edge beam design satisfying Article 4.6.2.1.4 of the AASHTO LRFD Bridge Design Specifications. However, there are circumstances where it may be more advantageous to place the flexure reinforcement along the skew rather than perpendicular to the walls. Examples may be culverts with short lengths, staged construction and large skew or shallow fills where an edge beam design requiring more slab depth may interfere with the roadway sub base. In these cases, the perpendicular span shall be used to design the slab thickness and the steel area.

- The steel area shall then be increased by the multiplication of $\sec^2\theta$ and the resulting area of steel placed along the skew. The skew, θ, is defined as the angle between a perpendicular line to the box culvert and the centerline of the roadway. Additionally, Article 5.5.4.2.1 of the AASHTO LRFD Bridge Design Specifications shall be satisfied such that the slab remains "tension controlled".

IMPLEMENTATION

In summary, all precast concrete box culverts and precast extensions of existing culverts, beginning with the January 20, 2012 letting, shall utilize LRFD by applying the standard designs of ASTM C 1577 and all CIP concrete box culverts and CIP extensions of existing culverts on the June 15, 2012 letting and beyond shall utilize LRFD according to the latest version and interims of the AASHTO LRFD Bridge Design Specifications.

Due to these time frames, it is possible to have a few scenarios that will require additional action. First, a LFD designed CIP box culvert may appear on some of the early 2012 lettings. If there is not a note stating otherwise on the plans, the contractor may still have the option to substitute a precast box culvert as permitted by Article 540.04 of the Standard Specifications. In these cases, a precast box culvert built according to ASTM C 1577 may be substituted provided the design requirements previously described are satisfied. To ensure all potential additional costs, such as PGE, are covered by the contract for this scenario, a BDE special provision of either "CONCRETE BOX CULVERTS WITH SKEWS ≤ 30 DEGREES REGARDLESS OF DESIGN FILL AND SKEWS > 30 DEGREES WITH DESIGN FILLS > 5 FEET (BDE)" or "CONCRETE BOX CULVERTS WITH SKEWS > 30 DEGREES AND DESIGN FILLS ≤ 5 FEET (BDE)" shall be inserted into each applicable contract document.

Second, the contract plans may originally have detailed a precast concrete box based on the old AASHTO M 259 or M 273 (LFD design) but the equivalent standard ASTM C 1577 (LRFD designed) precast concrete box culvert may require PGE, depending on the design fill. To ensure all potential additional costs, such as PGE, are covered by the contract for this scenario, the appropriate BDE special provision as mentioned in the previous paragraph, shall be inserted into each applicable contract document.

The Bureau of Bridges and Structures will coordinate with the Bureau of Design and Environment to insure contracts with culverts, let before June 15, 2012, have the appropriate special provisions inserted. If there are any questions regarding these policies please contact Gary Kowalski at (217) 785-2914.

KLR/kktABD11.3LRFDrevised-20111102