

## **PRECONSTRUCTION POLICY FOR THREE-SIDED PRECAST CULVERTS (8/25/2014)**

Historically, cast-in-place reinforced box culverts have been used with great success by the Cabinet for stream crossings. They provide a level of durability and long service life not available in similar structures. Site conditions and restraints may lead the project team to evaluate special use structures such as a precast three-sided concrete structure in addition to traditional structures. These guidelines shall be used in the evaluation of certain precast three-sided concrete structures in regards to structural applicability, hydraulic capacity and geometric shape.

Complete documentation of the decision process to implement three-sided precast concrete structures shall be submitted as described in Design Memo 03-06, Electronic Drainage Folder Submittal Requirements. Jobs generated outside the Division of Highway Design shall submit similar documentation to the Division of Highway Design, Drainage Branch or shall request assistance or advice from the Division of Highway Design. Three-sided precast concrete structures shall be produced by KYTC approved manufacturers and placed in accordance with Section 615 of the current Standard Specifications for Bridge and Road Construction. These guidelines constitute a revision to sections DR 604-1, DR 604-2 and DR 604-3 of the Division of Highway Design, Drainage Manual.

### **Site Evaluation**

Three-sided precast concrete structures are commonly referred to as three-sided culverts. Three-sided culverts may be a viable option for stream crossings and are most applicable at sites having shallow, non-erodible rock. Three-sided concrete structures may warrant consideration over more commonly used structures such as reinforced concrete boxes (RCBC) and traditional bridges if any of the following is desired:

- To provide quick construction to minimize road closure time
- To address the need to maintain a "natural" stream bottom
- To provide required aesthetics
- To satisfy special geometric or hydraulic constraints
- To minimize maintenance considerations
- To achieve a cost savings

Each site is unique and requires evaluation from a foundation and hydraulic perspective. The Division of Structure Design, Geotechnical Branch or designated prequalified geotechnical consultant is responsible for reviewing and approving the foundation design for three-sided culverts. The Division of Highway Design, Drainage Branch is responsible for reviewing and approving the hydraulic design for three-sided culverts.

Geotechnical review is vital in the selection of three-sided culverts. A geotechnical investigation and report is required for all three-sided culverts. Once a three-sided culvert has been identified by the project manager, designer or Project team as a possibility, a geotechnical investigation shall be requested. This request may be submitted after the Preliminary Line and Grade meeting or earlier if a three-sided option is identified. The geotechnical investigation shall determine the suitability of the foundation and describe all factors that limit or control the use of a three-sided culvert. The presence of erodible rock or absence of shallow durable rock may affect the selection of a three-sided culvert. In these situations, the geotechnical report may include recommendations for:

- A full width structural slab with apron and apron wall
- A paved flow line

- Extending the spread footing to competent bedrock
- Deep foundation support or
- Abandoning the three sided option

Abandoning the three-sided culvert option necessitates that the designer reevaluate the site and select a different structure type. A new structure requires an updated geotechnical review and recommendation.

### Selection Process

Three-sided culverts are divided into two classes – arches and flat tops. Arches approximate circular, parabolic or elliptical shapes with several variations. Flat tops are rectangular in shape and have haunches at the corners for added strength. To date, the Cabinet has approved the following commercial products for use as three-sided culverts:

- Conspan® Bridge Systems (arch)
- Hy-Span® Bridge Systems (flat top)
- Bebo® Bridge Systems (arch)
- Sherman Dixie Aqua-Arch Systems
- Ecospan™ Arch Systems

Standard details and geometric drawings for these systems are shown on the KYTC website in the file “KYTC Approved List of Three-Sided Concrete Structures” at: <http://transportation.ky.gov/Highway-Design/Drainage%20Manual/KYTC%20Approved%20Three%20Sided%20Culverts.pdf>. Special designs are available for these structures. The designer should contact the supplier for more information. Structure selection shall be based on hydraulic design.

### Hydraulic Design

The designer shall perform a hydraulic analysis in the selection of a three-sided precast culvert. General site analysis is based upon one of three categories – (1) replace an existing stream crossing with a similar stream crossing, (2) replace an existing stream crossing with a dissimilar stream crossing or (3) construct a new stream crossing. Three-sided culverts shall be hydraulically analyzed in one of two ways depending upon the situation:

- In accordance with FHWA publication, **Hydraulic Design Series 5 (HDS-5), Hydraulic Design of Highway Culverts** as implemented in FHWA’s computer program, HY8 (current version 7.3).
- In accordance with standard step back water methodology as implemented in the U.S. Army Corps of Engineers’ computer program, HECRAS (current version 4.1.0).

Both HECRAS and HY8 contain predefined three-sided shapes for culvert modeling but none for bridge modeling. The computational results between HECRAS culvert modeling and HY8 are not equivalent. HY8 does not perform standard step back water calculations or floodway analysis as is performed in HECRAS. Recreating or modeling an area containing a FEMA regulatory floodway cannot be accomplished in HY8. Hydraulic modeling shall follow the following guidelines:

- Stream crossings in a FEMA regulatory floodway shall be recreated and/or modeled in HECRAS.
- Replace an Existing Stream Crossing with a Similar Stream Crossing
  - If the existing structure is modeled as a bridge in HECRAS then the replacement structure shall be modeled as a bridge in HECRAS.
  - If the existing structure is modeled as a culvert in HECRAS then the replacement structure shall be modeled as a culvert in HECRAS.

- If the existing structure is modeled as a culvert in HY8 then the replacement structure shall be modeled as a culvert in HY8.
- Replace an Existing Stream Crossing with a Dissimilar Stream Crossing
  - If the existing and proposed stream crossings are appreciably different in terms of hydraulic equivalency or stream location, it is the designers' responsibility to select the most appropriate hydraulic modeling method.
  - It is recommended that HECRAS be used to model existing and proposed crossings when there are appreciable flows in the overbanks.
- Construct a New Stream Crossing
  - If there is no existing stream crossing, then it is the designers' responsibility to select the most appropriate hydraulic modeling method. An existing model includes an unencroached stream crossing..
  - It is recommended that HECRAS be used to model existing and proposed crossings when there is significant flow in the overbanks.
- Predefined shapes included in HECRAS and HY8 shall be used where possible to model three-sided structures. These shapes closely match the published geometries for Conspan, Aqua-Arch, Ecospan and Hy-Span three-sided precast products.
  - Bebo structure selections shall be submitted to the Drainage Branch for approval on a case by case basis prior to use.
  - None of the approved manufacturers produce all of the published shapes. Some of the published shapes do not exist as a predefined shape in HECRAS or HY8. In those instances, HECRAS or HY8 accepts user defined shapes. User defined geometries and modeling instructions for most of the three-sided concrete structures are available on the Cabinet's webpage. User defined shapes not found on the webpage shall be submitted to the Drainage Branch for approval prior to use.
  - Published flow areas as supplied by the manufacturer are based on an assumed horizontal line along the base of the shape. Structure or footer embedment, a concrete flowline or a natural bottom reduces the available flow area. The designer shall account for reductions in the published area of a three-sided shape to ensure that the available net flow area closely matches design conditions.
- The selection of a three-sided precast concrete structure shall include a comparison of the pre and post development water surface elevations of the design storm and of the check storm.

## Plan Preparation

The selected structures shall be listed on the situation survey sheet by series, base width, rise and total opening area. The designer shall attempt to identify at least one structure from each of the approved suppliers. If an approved supplier does not have a structure that satisfies design criteria then the supplier shall be listed on the situation survey sheet with the designation "NONE". Only one structure may be listed if no others satisfy design criteria. In that case, a note shall be shown on the plans stating that the selected structure was the only structure selected and the reasons for that selection shall be listed. Information critical to the design and/or function of the three-sided culvert shall be listed on the situation survey sheet. This includes but is not limited to:

- Culvert length along the centerline of the structure
- Wing wall lengths and angles
- Headwall elevations
- Wing tip elevations
- Foundation bearing pressure requirement
- Scour countermeasures (where applicable)

- Construction and plan notes

A three-sided culvert option shall be included in the roadway plans in addition to a traditional structure if the three-sided culvert is feasible but there is no clear functional or cost benefit of it over a traditional structure.

Subsurface data and pre-cast arch structure detail sheets will be provided by the Division of Structural Design, Geotechnical Branch (or consultant) to be included in the roadway or structure plans as appropriate. The subsurface data sheets provide the results of the subsurface investigation and include boring and laboratory testing information. The pre-cast arch structure detail sheet includes design and construction details needed to appropriately design and install the structure.

The Division of Structure Design shall be contacted by the designer in order to obtain a structure number (XXXX) for the three-sided culvert to be noted on the situation survey sheet as follows: "Drawing Number XXXXX shall be shown on the shop drawings and structure plans in accordance with current policy and shall be displayed on the structure in accordance with Standard Drawing BGX-006, current edition."

Sample general plan, subsurface data, pre-cast arch structure detail and situation survey sheets are provided on the drainage web site. Instructions are included that explain how the general notes shall be developed and included on the situation survey sheet. When it becomes necessary to attach guardrail to the structure, the guardrail notes shown for the general plan sheet shall be added.

### **Bid Items**

Bid items to perform this work include "3-Sided Culvert Linear Foot" measured in linear feet to include the structure, endwalls and foundation and "Foundation Preparation" measured as a lump sum for each structure. "Structural Granular Backfill" measured in cubic yards shall be used where critical backfill is needed. "Structure Excavation Solid Rock" will be needed for most projects to pay for work necessary to provide a relatively level rock surface on which to place the structure. Refer to section 603 – "Foundation Preparation and Backfill" and section 615 – "Precast Three Sided Structures" of the KYTC Standard Specifications for Road and Bridge Construction for more information.

### **Contractor Considerations**

The Contractor is responsible for submitting to the Department for review an electronic set of shop drawings for the selected structure. Upon review the drawings shall be updated as needed and resubmitted as structure plans with structure number in accordance with departmental policy. An electronic set of structure plans shall be submitted to the Department for inclusion in the project's electronic database and archive. The Division of Highway Design, Drainage Branch shall be notified of this event.

Special use structures often have assembly requirements not familiar to KYTC employees or to the Contractor. Extra consideration is needed from all involved parties to ensure a smooth plan generation and construction process. The general process for implementing special use structures include the steps listed below. Estimated times are shown in parenthesis. Times vary from project to project and are only presented to allow the designer to develop estimates that meet project completion dates.

- General design and layout information is determined in the design process and listed on the plans.

- Contractors determine requirements for these structures from the plans and proposal and consult with the suppliers of these structures to determine costs and scheduling for bidding purposes
- Once awarded the Contractor orders detail shop drawings from the supplier for the selected structure (4 weeks)
- Shop drawings are sent to KYTC departmental staff for review and comment and returned to Contractor (4 weeks)
- Plans are updated and resubmitted to KYTC as structure plans (2 weeks)
- The structure and its components are fabricated by the manufacturer or supplier and delivered to the site (8-12 weeks)

Based upon the above estimates, it may take up to 20 weeks from project award date before a structure may be delivered to the site. Road closure dates, maintenance of traffic and penalty clauses have to be given due consideration if a special use structure has been selected to ensure rapid construction and to minimize the duration of the road closure. Short allowable durations for road closure make planning and scheduling of all work elements critical.