

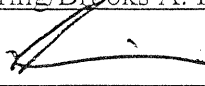
CITY OF TUCSON, ARIZONA  
DEPARTMENT OF TRANSPORTATION

ENGINEERING DIVISION  
ACTIVE PRACTICES GUIDELINE

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APPROVED BY:  DATE: November 14, 2006  
Andrew Dinauer, City Engineer

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**SUBJECT: BURIED CONCRETE ARCH CULVERTS**

**A. PURPOSE:**

To establish design and construction guidelines for buried concrete arch culverts supporting streets on the City of Tucson Major Streets and Routes Plan or subdivision streets to be accepted into the City of Tucson public street system.

**B. BACKGROUND:**

The buried concrete arch culverts most frequently proposed as substitutions for Arizona Department of Transportation (ADOT) standard reinforced concrete box culverts are not fully equal. The ADOT standard culverts are conservatively engineered to provide additional strength to account for the percentage of trucks that is known to exceed the statutory load limits, to provide a margin of safety against minor flaws in the construction that may result from field construction conditions, and to improve long-term durability and serviceability as the culverts experience thousands of heavy vehicle load applications and must resist the adverse effects of drainage over time.

On the other hand, concrete arch culverts can reliably support all AASHTO specified loadings, perform satisfactorily over an extended design life, and save the public money on the cost of construction, provided that they are carefully engineered and constructed. Because concrete arch culverts typically are not designed with the extra safety factors used in the design of the ADOT standard concrete box culverts, they require additional construction quality control measures in order to provide acceptable performance and design life. These guidelines establish the minimum design and construction requirements for buried concrete arch culverts to be accepted into the City of Tucson public street system.

## C. ENGINEERING DESIGN:

1. Buried concrete arch culverts shall be designed with a finite element soil-structure interaction computer analysis, in accordance with accepted research and industry standards. TDOT will accept analysis methods described in Simpson Gumpertz & Heger, Inc. (2001), *Summary of the Structural Evaluation of the Con-Arch System*, Highway Innovative Technology Evaluation Center (HITEC), Civil Engineering Research Foundation (CERF), American Society of Civil Engineers, and other acceptable soil-structure interaction analysis methods.
2. Designs shall comply with the American Association of State Highway and Transportation Officials (AASHTO) *LRFD Bridge Design Specifications or Standard Specifications for Highway Bridges*, latest edition. When using the Strength Design Method (Load Factor Design) or Load and Resistance Factor Design, the strength reduction factor,  $\phi$ , used in the design of the concrete arch shall comply with AASHTO specifications for concrete compression members.
3. Buried concrete arch culverts shall be designed and sealed by an Arizona Registered Professional Structural or Civil Engineer.
4. The minimum design vehicle load shall be the HL-93 or HS20-44 truck or tandem. The structure shall be designed to resist the maximum stresses resulting from all applicable AASHTO load groups and load combinations.
5. Foundations shall not be designed for allowable soil bearing pressures exceeding those permitted by the International Building Code or Uniform Building Code, unless greater allowable soil bearing pressures are justified by geotechnical engineering investigations performed and sealed by an Arizona Registered Professional Civil or Geological Engineer.
6. Hydraulic calculations shall be submitted verifying that the arch culvert has adequate flow capacity for the design discharge and will not result in unacceptable ponding upstream of the culvert or erosion upstream or downstream of the culvert. The hydraulic analysis shall be equivalent to the methodology contained in, and shall demonstrate that the arch culvert meets the requirements of, the approved project drainage report. The hydraulic design of the culvert shall conform to the City of Tucson Standards Manual for Drainage Design and Floodplain Management, December, 1989 (revised July, 1998), or appropriate and current hydraulic and drainage design standards approved by the Federal Highway Administration. Hydraulic calculations shall be sealed by an Arizona Registered Civil Engineer competent in culvert hydraulics.
7. Culverts shall be designed with inlet and outlet wingwalls, headwalls, and foundation cutoff walls designed to prevent culvert and roadway approach damage from slope stability failure, erosion, undermining or soil piping and shall, at a minimum, be equivalent to similar inlet and outlet features of ADOT standard box culverts.
8. Grading in the vicinity of the arch culvert should be designed to provide positive drainage away from the structure and its foundations.

9. Concrete arch culverts shall be designed with a minimum of two mats of reinforcing steel. Minimum reinforcing size shall be #4 deformed bars.

#### D. CONSTRUCTION:

1. Construction shall be in accordance with the City of Tucson/Pima County *Standard Specifications for Public Improvements*, latest edition.
2. Concrete arch structures on City of Tucson Major Streets and Routes shall be constructed of cast-in-place concrete, not shotcrete, unless the City Engineer grants specific approval in writing.
3. Concrete arch structures on City of Tucson subdivision streets may be constructed of cast-in-place concrete or shotcrete (spray-applied concrete). Shotcrete construction shall comply with the requirements in Section G of these Active Practices Guidelines.
4. Concrete shall be Type "S" concrete with Type II cement and minimum concrete compressive strength  $f'c = 3000$  psi or greater.
5. Forms may be conventional wood or steel forms, or other forming systems approved by the Engineer. The use of balloon forms shall not be permitted.
6. All reinforcing steel shall be secured in position such that it does not shift in position during concrete placement.
7. Construction joints are not required in floor slabs, except at cold joint locations. Joints in top slabs, arches and walls shall be spaced at 30-foot centers, maximum.
8. For multiple span concrete arch culverts, positive drainage shall be provided for all "valleys" between individual spans, to prevent the accumulation of drainage water in these valleys. Acceptable drainage measures may consist of a waterproof sealant on the top surface of the valley, a "French drain" consisting of granular material or a perforated pipe running the length of the valley, and a positive drain to discharge water accumulating in the valley, or other acceptable drain designs.
9. Construction shall comply with all general notes, special provisions, plans, sections, and details prepared by the design engineer of record.

#### E. CONCRETE CURING AND FORM REMOVAL:

The concrete forms perform two important functions. They support the weight of the concrete until the concrete gains sufficient strength to safely support itself and the earth fill material without cracking or deforming, and the forms retain moisture in the slabs and walls to prevent rapid evaporation and shrinkage cracking and to enable the hydration process for the concrete to be completed. Removing the forms on the basis of a concrete strength test can address the strength issue, but that will not substitute for the curing provided by leaving the forms in place.

Accordingly, prior to casting any concrete, the Contractor shall submit to the Engineer a concrete curing and form removal plan detailing how the concrete curing and form removal shall comply with the following minimum requirements:

1. Concrete curing shall be in accordance with Sections 601-3.06 and 1006-6 of the *Standard Specifications*. When weather conditions with high temperatures and low humidity likely to accelerate concrete shrinkage cracking are forecast for the day of concrete placement, the top slabs of concrete arch culverts shall also be cured in accordance with Section 1006-6(E) of the *Standard Specifications*.
2. Form removal shall comply with one of the following methods:
  - a. The forms shall be left in place for the full time period required for "Deck Slabs" in Section 601-3.02(D) of the *Standard Specifications*, or
  - b. An airtight bulkhead constructed of plywood or other durable material approved by the Engineer shall be constructed across one end of all culvert cells to prevent the "wind tunnel" drying effect, and
    - 1) A minimum of 5 days has passed since placement of the concrete or shotcrete occurred and test samples reveal that 100 percent compressive strength has been achieved, or
    - 2) A period of 10 days has passed since placement of the concrete or shotcrete occurred and test samples reveal that 70 percent compressive strength has been achieved, or
    - 3) A period of 24 hours has passed since placement of the concrete or shotcrete occurred, the test samples reveal that 80 percent compressive strength has been achieved, and the interior surfaces shall be cured using the Water Curing Method as specified in Section 1006-6.01(B) of the *Standard Specifications*.

F. CONSTRUCTION QUALITY CONTROL:

1. The Contractor shall provide a special inspector certified by the City of Tucson or a Registered Professional Structural or Civil Engineer who shall provide Special Inspection as required by the City of Tucson Development Services Department for concrete construction and foundation soils.
2. The Contractor shall provide all materials submittals, shop drawings, inspection and testing required by the *Standard Specifications* for concrete, reinforcing steel, concrete formwork, excavation, preparation of foundation soils, and backfill.

G. SHOTCRETE CONSTRUCTION:

For those concrete arch culverts where shotcrete (spray-applied concrete) construction is permitted, namely those culverts on City of Tucson subdivision streets or on Major Streets and Routes only with specific written approval from the City Engineer, the following requirements apply:

1. Prior to the start of shotcreting operations, the Contractor shall submit for approval the names of all shotcrete application nozzle operators and a summary of each operator's experience verifying that he or she has a minimum of three years of recent experience in the application of shotcrete for heavy construction structures and has successfully completed at least five shotcrete heavy construction structures that have been approved by the engineer responsible for certifying compliance with the construction drawings and specifications.
2. The Special Inspector shall observe the shotcrete application process, to assure that all shotcrete is densely consolidated without voids and the full concrete thickness indicated on the construction contract drawings is achieved.

#### H. VALUE ENGINEERING PROPOSALS:

1. For TDOT capital improvement projects where concrete arch culverts are proposed as Value Engineering substitutions for ADOT standard concrete box culverts, TDOT reserves the right to refuse to accept the substitution unless the City Engineer determines that (a) the substitution of a concrete arch culvert is appropriate for the project and (b) the amount of the cost savings to the City of Tucson justifies accepting the Value Engineering proposal.
2. The Contractor shall provide, for review and approval by the Engineer:
  - a. A location drawing showing the basic geometrics for each culvert.
  - b. All of the hydraulic and structural calculations related to the proposed design.
  - c. A geotechnical engineering report, if required to verify allowable foundation soil bearing pressures.
  - d. Construction drawings required to construct the culvert(s).
  - e. A detailed cost estimate.
3. The hydraulic calculations shall demonstrate that the culverts are hydraulically equivalent to the drainage structures shown or specified on TDOT's capital improvement project plans.
4. Any modifications of the channel upstream or downstream required for the substitution of concrete arch culverts require approval of the Engineer and shall be included in the Value Engineering proposal.
5. The design shall meet the roadway and channel vertical profile requirements shown in the project plans.
6. The design shall include all required modifications to manholes, junction structures, side inlets, balance ports, grate inlets and miscellaneous items as shown in the project plans.
7. Any modifications to utilities or traffic control due to the arch culvert(s) shall be included in the Value Engineering proposal and shall be subject to the Contractor's design and submittal for review, comment and approval by the Engineer, prior to final acceptance and construction.

#### I. MEASUREMENT AND PAYMENT

Reinforced concrete arch culverts and all related appurtenances will be measured by the completed structure in place on a lump sum basis per each arch culvert. The lump

sum amount includes excavation and backfill of culvert foundations, formwork, concrete, reinforcing steel, adjoining concrete headwalls and wingwalls, concrete or other traffic barriers, toedowns, joints, structural steel, storm drain items, manholes (including rings and covers), waterproofing, labor, curing, equipment, and all other materials and work related to construction of the culvert structure. All arch culvert design costs and any necessary utility or project modifications are included in the lump sum price.

J. BASIS OF PAYMENT

Concrete arch culverts and all related appurtenances, for each structure, measured as provided above, shall be paid for at the contract price, complete in place.

K. REPAIRS:

In the event that the City Engineer determines that the arch portion of a newly constructed concrete arch structure has an excessive and unacceptable amount of cracking, or other indications of distress, the City Engineer may direct that the Contractor perform load testing of the structure in accordance with AASHTO load testing specifications and/or the City Engineer may direct that the minimum repair for cracked arch structures be performed by the Contractor.

The minimum repair for excessive and unacceptable cracking in the arch portion of a concrete arch culvert shall consist of removing earth fill materials over the structure, cleaning the top of the structure, installing a waterproof membrane over the top of the structure, and replacing the earth fill, roadway pavement and other improvements.

If the structure fails the load test, the City Engineer may direct additional repairs, in accordance with the *Standard Specifications*.