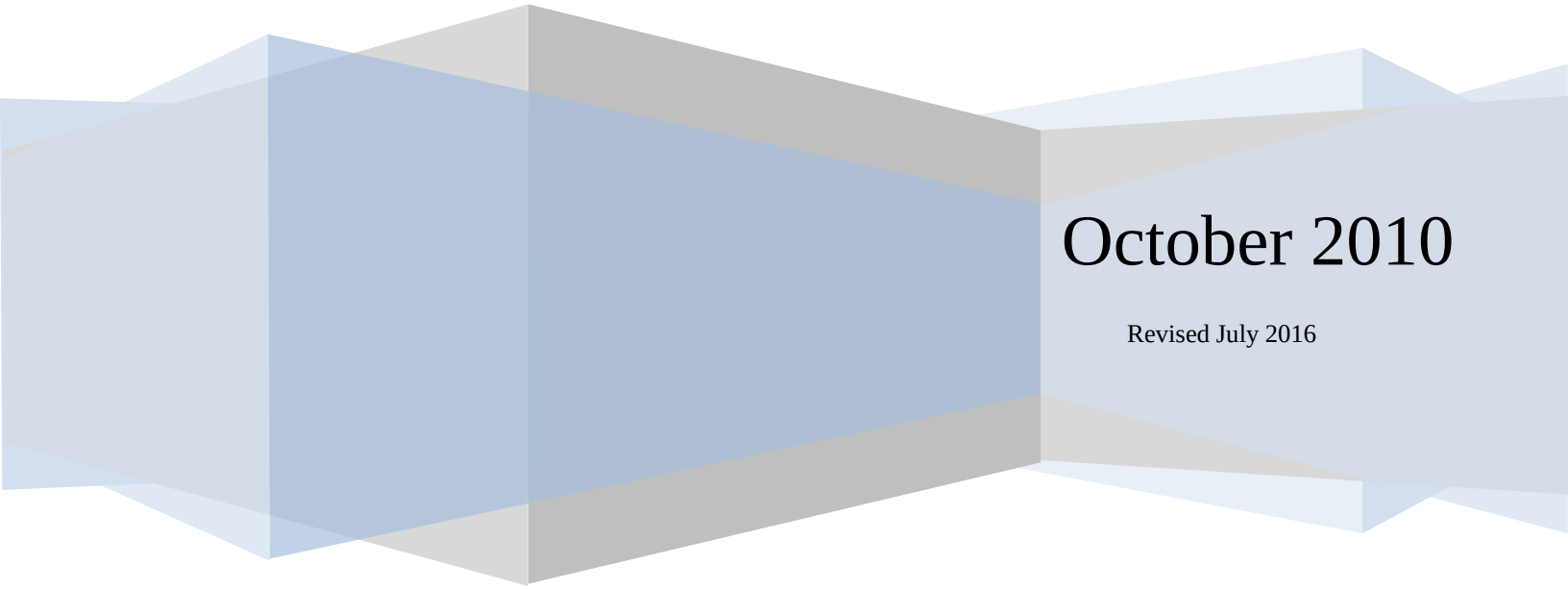
Missouri Department of Transportation

Reference Guide SBC

For Laying Out and Plan Reporting Details of Concrete Single Box Culverts (SBC) Using Missouri Standard Plans for Highway Construction

Prepared by the Bridge Division



October 2010

Revised July 2016

PART 1: INTRODUCTION

1.1 Purpose of the Guide

The Reference Guide is intended to be used as a reference when laying out and plan reporting details of Concrete **Single Box Culverts (SBC)** on the Roadway Plans using the Missouri Standard Plans for Highway Construction. Guidance is given to explain in part the strategy and design methodology in using the Missouri Standard Plans for SBC design while terminology is defined and clarified. While the highway designer will gain the most benefit in utilizing the Guide, it is equally usable by any culvert designer or end user wanting to know the background of standardized SBC design in more detail.

Generating a final culvert design requires using a composition of many design aids and documents identifying hydraulic, structural, and other non-hydraulic considerations. The term *nonhydraulic considerations* is used in the Engineering Policy Guide (EPG) to distinguish between those considerations dealing with sizing the culvert opening based on hydraulic flow and everything else. The Reference Guide concentrates on identifying and explaining structural considerations in using the Standard Plans; it explains terms and details typical to designing box culverts; it gives hints of some potential concerns and addresses some known specific application concerns. The Guide will also serve to explain areas of information believed to be important for the highway designer in completing a SBC design for inclusion on the Roadway Plans after hydraulic considerations, in effect the type and size of the SBC, have already been determined. This includes understanding the level to which the details should be reported on the Roadway Plans and how the reporting of these details and communication internally with MoDOT Construction can avoid conflicts later.

The Reference Guide is a collection of information written not in any particular order but intended as a repository for storing useful information for the highway designer. To this end, the Reference Guide is easily revised and therefore should be appended as required for any unintentionally omitted but important information or any important new information as it is developed at a later date.

1.2 Organization of the Guide

The Guide is organized in FIVE parts:

Part 1: Introduction
Part 2: Using the Standard Plans
Part 3: Interpreting the Standard Plans
Part 4: The Culvert Quantities Programs
Part 5: Other Considerations

1.3 Other Engineering Policy Guide References

(Reference list given is specific to concrete box culverts and may not be complete; provided as an aid only.)

EPG 750.2.11	Data Required on Plans	*Guidelines used for plan reporting details.*
EPG 750.7	Non-Hydraulic Considerations	*Guidelines used for nonhydraulic considerations.*
EPG 750.7.2.7	Multiple Opening Installations	
EPG 750.7.3	Environmental Requirements	
EPG 750.7.4	Box Culverts	
EPG 750.7.8	Fill Settlements	
EPG 750.7.9	Camber in Culverts	

EPG 750.7.10	Culvert Extensions	
EPG 750.7.11	Overfill Heights	
EPG 750.7.13	Culvert Lengths	
EPG 751.1.2.7	Box Culverts	*Guidelines used for preliminary design of any concrete box culvert by the Bridge Division*
EPG 751.8	LRFD Concrete Box Culverts	*Guidelines used for the structural analysis and design of any concrete box culvert and used by the Bridge Division for developing the standard single concrete box culvert tables. The beginning articles do provide a very thorough description of the loads that act on culverts and how they are estimated. It also includes how the design fill is estimated.*

PART 2: USING THE STANDARD PLANS

2.1 User Expectations

Primary users of the Missouri Standard Plans for Highway Construction for SBCs are:

Highway Designer – Determines SBC design fill, type, size (opening), concrete and steel quantities for letting
Contractor – Backchecks SBC lengths, joint layout and quantities for bidding, and if awarded, then for building
Construction Inspector – Backchecks SBC lengths, joint layout and quantities for validating contractor estimates

First, the Missouri Standard Plans for Highway Construction is used by the highway designer as a reference of all the completed standard SBC types and sizes available for selection and use on a project. After which, the highway designer references this information to a contractor to retrieve all of the structural information necessary for construction of the selected SBC. The key here is that after the highway designer selects a standard SBC candidate that satisfies hydraulic and geometric constraints, they must give the relevant information on the Roadway Plans in order to refer the contractor to the correct construction drawings (Standard Plans), pay quantities. This information includes the *design fill*, *type*, *size* and *orientation (skew)* of the culvert and the concrete and steel reinforcement pay quantities (See "Program" for estimating quantities):

> For *design fill*, see 3.2 Earth Fill, *Design Fill* and CL Roadway Fill. The *type* of culvert typically refers to most particularly the inlet wing type used, either straight or flared, and is denoted on the Standard Plans. It does not refer to the type of construction to be done, either new or extension (rehabilitation) or staged. The *size* of course is the span (S) x height (H) of the single cell and may also refer to the length of the culvert. The *orientation* refers to the skew, either squared or skewed. In general, this kind of information, referring to culvert specificity, can only be determined by the highway designer since it is project specific and based on need, and geometric and hydraulic constraints.

Second, the Missouri Standard Plans for Highway Construction is then used by a contractor to bid, and then, if awarded, to construct the SBC. The information given on the Roadway Plans such as the *design fill*, *type*, *size* and *orientation* of a SBC is utilized by the contactor to reference and extract the structural information from the Standard Plans which in combination gives the complete layout and details of what needs to be constructed.

Third, the Missouri Standard Plans are used by the construction inspector overseeing the construction of the SBC. Inspectors layout the culvert using the information from the Roadway Plans and the Standard Plans, estimate concrete areas and build steel reinforcement barbills reaffirming concrete and steel quantities, in order to work with and back check the contractor on his material orders and costs. This is standard procedure in the field.

2.2 Reporting Information, Reproducibility and Responsibility

The highway designer should report all the relevant SBC design and detail information that completely defines the proposed SBC on the Roadway Plans. This includes *design fill, type, size* and *orientation*. Also included are: *roadway geometry, profile grade, cross slopes, superelevation, steel and concrete quantities, transverse joint locations (identifying sections essentially does this), and guardrail attachments* as appropriate. And equally important, *all SBC sections including end sections and cut sections should be identified by number or letter on the* Roadway Plans.

The design fill for each section shall be reported on the Roadway Plans. Multiple sections using the same design fill shall be identified. There is no practical limit to the number of different design fills (different SBC units) that can be reported on the Roadway Plans except that repetition of the same design fill (or the number of same SBC units reported using the same design fill) could reduce construction costs. Keep this in mind particularly for short

SBCs and long SBCs under shallow earth fill, especially long SBCs under divided highways and medians with shallow fills. However, using different design fills is reasonable and recommended for long SBCs, especially long SBCs under widely varying earth fills where future loading is anticipated to not change significantly over the design life of the culvert, taken to be 75 years. Material cost savings could justify this direction. See EPG 750.7.11.2 Design Fill Heights.

Instructions for determining the barrel length and laying out transverse joints for new culverts are given on the Standard Plans. Equations are given for determining the barrel length, and maximum barrel length criteria and maximum cut section length criteria are also given. See EPG 751.8.1.3 Barrel Section Dimensions.

The Standard Plans also give guidance for locating transverse joints. It is included to be used by the designer. For design fills less than or equal to 2 feet, it is critical that the transverse joints be located from under the traveled way for structural reasons. See "Laying out Transverse Joints" in this Guide. Since this information is equally available to the contractor, if omitted on the Roadway Plans, it can easily be used by a contractor in laying out a culvert. However, this should be prevented. See EPG 750.7.11.2 Design Fill Heights and EPG 751.8.3.1 Joints for more guidance on laying out transverse joints.

Because all of this information is on the Standard Plans, the work of the highway designer is on display and able to be reviewed. The information on the Standard Plans is included for the Highway Designer to utilize; the Contractor to reproduce, in a sense, and backcheck and to build from; and the Construction Inspector to reproduce and backcheck and to validate contractor quantities. If information is missing, it will have an impact and create more work later which can add cost.

In the past, there have been issues with incomplete SBC information on the Roadway Plans. While it is true that if not given enough information on the Roadway Plans, a contractor could still build a SBC from the Standard Plans although this is to be avoided. Good design practice would dictate that in order to lower risks and costs, the highway designer most familiar with the work, the project and the future of the system is in the best position to lay out and provide the best details for the construction of the SBC.

2.3 *Standard* and *Nonstandard* Concrete Single Box Culverts

Standard concrete box culverts are any concrete box culvert structurally analyzed in accordance with EPG 751.8 LRFD Concrete Box Culverts and given on the Standard Plans. *Standard* concrete box culverts are tabulated concrete box culvert designs and details given on the Standard Plans that range in opening and design fill depth. These are completed culvert designs with details meeting the structural design and detailing requirements of EPG 751.8 LRFD Concrete Box Culverts. Standard Plan culverts are arranged in series with sizes beginning at 3 feet x 2 feet [Span x Height] and increased incrementally 1 foot in span up to a span of 16 feet. The design fills range from 1 foot up to 50 feet inclusive generally in 2 foot increments.

The term *nonstandard* is heavily used and given to describing concrete box culverts with openings and design fills that are outside the Standard Plans ranges. Though single box culvert designs that are not included in the Standard Plans are called *nonstandard* since they require a special design (See EPG 750.7.11.3 Maximum Fill Heights), their designs must still conform to the structural design and detail standards required for all concrete box culverts used on the system. Therefore, any nonstandard box culvert using either *standard* or *nonstandard* details must be in accordance with EPG 751.8 LRFD Concrete Box Culverts. Contact Bridge Division for further guidance.

Standard single box culvert designs shall always be used when possible.

(Above also applies to double and triple concrete box culvert designs as shown on the Standard Plans.)

2.4 Pipe Inlets

Adding pipe inlets at SBC walls does not deter using the Standard Plans SBC designs unless placement of the inlet does not meet the conditions in accordance with Standard Plans 703.60 as shown. This can occur, for example, when the pipe diameter is greater than the wall height, or when the pipe diameter and/or placement of a pipe precludes the development (required embedment) of the steel reinforcement in the wall and including either the top or bottom slab, or when the invert elevation is in conflict with the elevation of the top of the bottom slab and development of the steel reinforcement. Contact the Bridge Division for a special design.

2.5 Other Standard Plans References

703.10	SBC Standard Details (Straight Wings-Squared)	*Use to reference culvert details*
703.11	SBC Standard Details (Flared Wings-Squared)	*Use to reference culvert details*
703.12	SBC Standard Details (Straight Wings-Left Advanced)	*Use to reference culvert details*
703.13	SBC Standard Details (Flared Wings- Left Advanced)	*Use to reference culvert details*
703.14	SBC Standard Details (Straight Wings-Right Advanced)	*Use to reference culvert details*
703.15	SBC Standard Details (Flared Wings- Right Advanced)	*Use to reference culvert details*
703.16	SBC Standard Details (Cut Section)	*Use to reference culvert details*
703.17	SBC Tables of Completed Designs	*Use to determine member sizes and steel reinforcement from design fills and culvert openings*
703.37	Exterior Wing Reinforcement	*Use to determine wing reinforcement for quantities*
703.60	Concrete Box Structure Pipe Inlet	*Use if pipes enter culvert walls*

PART 3: INTERPRETING THE STANDARD PLANS

3.1 "Equations for Computing Alpha, Beta, B and C"

A delineated box on the first Standard Plans sheet of each SBC type shows the "Equations for Computing Alpha, Beta, B and C". These equations are used to compute the SBC layout dimensions. A reasonably accurate and reproducible set of layout dimensions should be calculated by the highway designer. The highway designer will use some of the dimensions for estimating the concrete and steel reinforcement quantities using the Single Box Culvert Quantities LRFD software program (See *"Single Box Culvert Quantities LRFD"* Program). Since the geometric layout (dimensions) is not given on the Roadway Plans, the contractor will also need to determine the layout dimensions using the Standard Plans based on the proposed roadway grade and width that are to be given on the Roadway Plans.

3.2 Earth Fill, *Design Fill* and CL Roadway Fill

Earth fill is the actual calculated fill depth (ft) estimated by the highway designer. It is measured from the top of the top slab to the top of the roadway, side slope or earth cover. It is used to determine the *design fill* that is to be reported on the Roadway Plans for each section of a SBC.

Design fill is the nominal fill depth (ft) and is a representative (derived) fill estimated by the highway designer. It represents a single and reasonable approximation of the varying earth fill along the full length of each section of a SBC to be used for the design of each section of a SBC. Varying earth fill may be either calculated or plotted for each section and should be determined considering both directions, i.e. lengthwise (normal to span) and widthwise (parallel to span) for each section of a SBC. See EPG 750.7.11.2 Design Fill Heights for guidance in determining *design fill*.

The tabulated *design fill* on the Standard Plans is the earth fill depth for which the given SBC was designed and is used only to determine the SBC member thicknesses and steel reinforcement bar sizes and spacing. The tabulated *design fill* includes fill dead load and vehicular live load effects though live load effects will not be determined by the highway designer. Vehicular live load effects are included as part of the tabulated *design fills* given on the Standard Plans as a matter of convenience and its effects become less with *design fill* depth. As a consequence of this, SBC sections not directly under the roadway will in effect be designed for live load though the section may experience dead load fill only.

Design fill is used by both the highway designer to estimate quantities and the contractor to determine quantities and the barbill.

Design fill is also used in the culvert quantities program to determine which details for longitudinal steel reinforcement are used.

The dimension *CL Roadway Fill* is shown on the Standard Plans and is just the earth fill depth measured from the top of the top slab to the top of the centerline of the roadway. It is used in the "Equations for Computing Alpha, Beta, B and C" that determine the SBC layout dimensions. If this dimension is not accurately known, it should not be given on the Roadway Plans in order to allow for adjustments in the field. The contractor will need to estimate this fill depth in order to determine the layout.

3.3 Estimating and Reporting *Design Fill*

Estimate the design fill in accordance with EPG 750.7.11.2 Design Fill Heights.

Report the *design fill* for each section of a SBC on the Roadway Plans.

It is not necessary for the estimated *design fill that* is to be reported on the Roadway Plans to match a tabulated *design fill* given on the Standard Plans. Instructions are given on the Standard Plans for how to determine member thicknesses and steel reinforcement when the estimated *design fill* reported on the Roadway Plans is between tabulated *design fills* given on the Standard Plans or when the two do not match.

The estimated *design fill* does not need to match the centerline of roadway fill which is not given on the Standard Plans but estimated using the Standard Plans. The centerline of roadway fill is used to determine the layout of the SBC only.

When cut sections are used the *design fill* shall be reported for each cut section and each end section. This is highly recommended for long and/or large culverts where a reduced *design fill* for a section or sections of a total SBC length can lead to significant cost savings. The centerline of roadway fill is used by the contractor in laying out the culvert and may be reported on the Roadway Plans if considered necessary.

When the *design fill* is less than 1 foot the Standard Plans are not applicable. Similarly, when the *design fill* exceeds 50 feet the Standard Plans are not applicable.

SBC sizes not given shall not be interpolated between SBC sizes given. If a SBC size is not explicitly shown on the Standard Plans, then the SBC is nonstandard and will need a special design. Contact the Bridge Division.

When cut sections are located completely outside the traveled way, the high ¾ point of earth fill depth should be used as the *design fill*.

When any part of cut sections are located under the traveled way, two conditions should be investigated: (1) If the earth fill is not significantly varying and if any part of the cut section is under less than 2 feet of earth fill, then 2 feet of earth fill should be used as the *design fill* to be reported on the Roadway Plans, and (2) If the earth fill is significantly varying and if any part of the cut section is under less than 2 feet of earth fill, then the earth fill to be used as the *design fill* should be that which will produce the greatest member thicknesses and greatest steel reinforcement areas.

Report the design *fill* for each section of a SBC on the Roadway Plans. This will avoid confusion later in the field. Remember that the field will need to calculate concrete and steel quantities based on using the Standard Plan tables which require knowing *design fill*, *type* and *size*. As a final check, be sure all three are identified on the plans for later users.

3.4 Design Vehicular Live Load

Determining the type of live load is NOT a condition for using the Standard Plans in order to specify a SBC. Past editions of the Standard Plans based on AASHTO Standard Specifications for Highway Bridges (LFD) required the highway designer to know, select and plan report a live load based on NHS route status and route commercial zoning. This is no longer necessary since standard designs are based on AASHTO LRFD Bridge Design Specifications which considers only a single design vehicular live load, or HL-93. This is noted in the General Notes on the Standard Plans.

3.5 Laying Out Transverse Joints

Direction is given on the Standard Plans for the highway designer.

Transverse joints are not allowed to be located under the traveled way for design fills less than or equal to 2 feet for structural reasons. The top slab culvert edges have less strength than the interior slab sections and therefore live load should be reduced at these edges. Transverse joints may be placed under the traveled way for design fills greater than 2 feet however follow the guidance as shown in EPG 750.7.11.2 Design Fill Heights and EPG 751.8.3.1 Joints. Note that shoulders are excluded from the traveled way.

If a transverse joint is necessary on skewed culverts and cannot completely clear the traveled way the joint should be located closer to the headwall or closer to the center of the median if available.

Note that transverse joints cannot be located closer than 3'-0" to the inside face of the headwall so that the sloping wing steel reinforcement, the J1 bars (J6 bars for flared wings), can be developed (embedded) in concrete for strength resistance. Also, by requiring a 3'-0" limit, the location of the first transverse joint matches the minimum requirement used in the culvert quantities programs. Lastly, by maintaining 3'-0" min. to the first transverse joint, it allows for a more robust end section with a sufficient top slab barrel length to resist live load supplementary with the headwall/edge beam resistance and more capable of resisting hydraulic, undermining and erosion forces suitably.

3.6 Flow Line Elevations

Flowline elevations shall be reported on the Roadway Plans properly indicated and identified as Elevations 1 and 2 corresponding to upper and lower flow line elevations similar to the Standard Plans. These elevations may be below the natural stream bottom in accordance with EPG 750.7.3 Environmental Requirements. Also, see EPG 750.2.11 Data Required on Plans.

PART 4: THE CULVERT QUANTITIES PROGRAMS

4.1 *"Single Box Culvert Quantities LRFD"* Program

The box culvert quantities program shortcut for concrete SBCs is provided in ***R:\Design Applications\Culvert Quantities*** and is available for use by all districts. It will allow the user to generate concrete and steel reinforcement quantities based on the design fill, type, size, orientation and length of the proposed culvert. The program can process multiple cut sections with independent design fills and section lengths.

There are three culvert quantities programs available, one for each of the three fundamental types of concrete box culverts: *single box culvert, double box culvert* and *triple box culvert*. Each program is uniquely identified by its program name shortcut:

R:\Design Applications\Culvert Quantities\Single_Box_Culvert_Quantities_LRFD.bat - Shortcut
R:\ Design Applications\Culvert Quantities\Double_Box_Culvert_Quantities_LRFD.bat - Shortcut
R:\ Design Applications\Culvert Quantities\Triple_Box_Culvert_Quantities_LRFD.bat - Shortcut

The single box culvert quantities program is predominantly used by designers in computing the concrete and steel quantities to be included on the "2B" sheets of the Roadway Plans. The double and triple box culvert quantities programs are used predominantly by the Bridge Division for the same reason. However, in the past, districts have requested the use of the multiple cell quantities programs to compute concrete and steel quantities for the purpose of preliminary estimating. Therefore all three programs are provided for use by districts. If any of these programs are unavailable, please contact the Bridge Division.

All three programs can estimate quantities for standard box culverts.

[NOTE: All three programs can estimate quantities for some nonstandard box culverts. The programs can process some nonstandard culvert openings and design fills, but the Bridge Division must perform all nonstandard SBC designs which are not included on Standard Plans 703.17. Bridge Division is responsible for confirming that Standard Plans 703.10 – 703.16 details are still adequate. Contact the Bridge Division for special designs.]

This program is not available for use by MoDOT Construction personnel. Any information produced from the program should be forwarded to MoDOT Construction for their use. This program is capable of producing a barbill in MicroStation. **Therefore, a copy of the output file and barbill should be forwarded to the Office of the Resident Engineer for coordination of materials information with the contractor.**

4.2 Generating a Barbill

The culvert quantities program *Single Box Culvert Quantities LRFD* will allow the user to generate a steel reinforcement barbill. It is not provided with the contract documents. This is useful information primarily for after the culvert is awarded. The Resident Engineer's Office responsible for overseeing the construction inspection of the box culvert should be informed that a barbill can be made available for any box culvert shown on the Roadway Plans and it should be incumbent upon the highway designer to notify, provide and coordinate the transfer of this useful information preferably and immediately after award (or at such time as decided by the Core Team).

PART 5: OTHER CONSIDERATIONS

5.1 Special Designs

Special designs are necessary when any one of the standard criteria used to develop the standard SBC as shown on the Standard Plans for SBC is not satisfied. Sometimes these are referred to as "Special Sheet" box culverts since the details of the special designs are included on the Roadway Plans as special sheets. Requests for special designs shall be made to the Bridge Division. Requests for special design should include a deadline and a reasonable expectation of time for completion.

Requests to Bridge Division from Districts for special designs shall be for structural design and detailing only (See EPG 750.7.4.3 Summary of Responsibilities). Hydraulic performance is presumed to be finalized.

[NOTE: Other types of design review may be requested but historically the requests have been structural.]

Details and quantities are prepared by the Bridge Division and returned as a special sheet or in any other preferred format by the highway designer.

5.2 Zero Fill Condition

The Standard Plans shall be used for design fills between 1 foot and 50 feet for the culvert opening specified. Design fills that are less than 1 foot or when the SBC is used as the riding surface (zero fill condition) are not completed Standard Plan designs and not allowed to be shown on the Roadway Plans. Contact the Bridge Division for these special design culverts.

End sections on long box culverts or box culverts under low design fills are the exceptions where the side fills run out and flatten. Another example is median box culverts where this can happen also. Typically, these sections are designed similarly to adjacent sections using a greater design fill.

5.3 Parallel Culvert Headwalls

Standard SBCs have parallel headwalls when the culvert is squared with either straight or standard twenty-degree flared wings, or skewed with straight wings. When standard SBCs are skewed with standard twenty-degree flared wings, the headwalls are nonparallel and the headwall with the twenty-degree flared wings is detailed normal to the centerline of the box culvert. Both conditions are standard and readily developed into completed standard design as given in the Standard Plans tables. Any other headwall or wings configuration presents detailing complexities that reasonably are not considered standard.

If there are geometrical/layout/staging/construction conditions where parallel headwalls with flared wings are justifiable and the culvert/wing type is a nonstandard SBC, both the Standard Plans culvert tables and the box culvert quantities programs cannot be used. Core team review is required. Special detailing is required; the design of the bottom slab between wing walls would need to be specially designed and the Bridge Division should be contacted. Hydraulically, the culvert should still operate the same.

5.4 Clear Zone and Use of Guardrail on Culverts

For information on clear zones, see EPG 231.2 Clear Zones. For use of guardrails on culverts, and for design and details of guardrail to be attached to culverts, contact the Bridge Division.

5.5 Benchmarks

Use of benchmarks on new culvert designs for the purpose of permanently recording and displaying NGVD data to be attached to a culvert is a Core Team decision. If decided to use, the details shall be provided either on the Roadway Plans or to the Construction Field Office responsible for construction inspection for inclusion on the project.

5.6 Abrasion

Standard SBCs were designed without considering abrasion for the design of the bottom slabs and exterior walls.

Abrasion is the wearing away of exposed concrete due to the movement of large rocks or boulders by heavy or fast stream flows in terrain where this type of a flow regime and geological load are possible. AASHTO LRFD Bridge Design Specifications defines abrasion as loss of section or coating of a culvert by the mechanical action of water conveying suspended bed load of sand, gravel, and cobble-size particles at high velocities with appreciable turbulence.

In Missouri, there is little evidence to support designing concrete box culverts for abrasion. In the past, standard and nonstandard box culvert designs did consider abrasion resistance by including a ½" monolithic wearing surface meaning that up to ½" of concrete on the interior surfaces (stream faces) of the bottom slab and walls was sacrificial which after wearing away would not diminish the structural capacity required. Realizing that abrasion frequency and the potential for abrasion were rare, the sacrificial ½" monolithic wearing surface was considered overdesign and therefore not included as part of the new box culvert standards and in fact for any new concrete box culvert design.

If abrasion is a concern, it should be considered on a case-by-case basis and it is strongly recommended that FHWA[1] or NCHRP[2] guidelines be reviewed before abrasion is to be considered in culvert design. The Core Team is responsible for determining if abrasion is a concern. For new culverts, this may be difficult, but for either replacement or extension box culverts, there may be visible evidence clearly supporting designing for abrasion. In either case of new, replacement or extension, the culvert must be uniquely designed and is nonstandard, and Bridge Division should be contacted.

[Technical Note: Abrasion is considered to be potentially worse nearer the middle of a bottom slab span where stream flow is less alterable and velocities are greatest, accounting for abrasion by considering that a ½" monolithic (sometimes referred to as 'integral') wearing surface will likely be removed will have no actual effect on culvert strength. Removal of a ½" of slab is only significant at locations along the interior bottom slab surface where the concrete is in compression, i.e. at the corner where the slab meets the exterior walls. For the exterior walls, typically they are in tension on the inside face and slenderness effects are considered. Also, consideration should be given to the fact that culvert boxes are actually made up from four rigidly attached diaphragms but are ideally and conservatively modeled and designed as 1-foot strip width beams. All of these points to the fact that designing for an integral wearing surface is over conservative and capacity need not be unnecessarily increased.]

[1] FHWA. 1985. *Hydraulic Design of Highway Culverts*, FHWA-IP-85-15. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, Hydraulic Design Series No. 5

[2] NCHRP. 1978. "Durability of Drainage Pipe." *NCHRP Synthesis of Highway Practice No. 50*. Transportation Research Board, National Research Council, Washington, DC, p. 37.

5.7 Epoxy Coated Reinforcement

Standard SBCs were designed using uncoated steel reinforcement sometimes referred to as nonepoxy coated steel reinforcement.

Use of epoxy coated reinforcement (ECR) is not warranted unless the design fill is less than 1 foot and especially when the box culvert top slab is used as riding surface, conditions which are outside the range of design fills used for standardizing box culverts. Using ECR also requires that the embedment depth and splice lengths of the steel reinforcement bars be adjusted, always deeper and longer respectively, which could lead to increases in bar sizes and member thicknesses, specifically the top slab and exterior walls, conditions which are outside the design breadth and intent of standardizing box culverts. Other considerations for use of ECR, for example, could include the climate conditions, salting frequency, roadway profile grade, AADT, and length of span. This means that using ECR in a box culvert is considered nonstandard and a special design is required.

Another complication is the degree to where ECR should be used in box culverts and is subject to review and discussion. The argument goes that only the topmost bars in a box culvert considered more severely exposed to chlorides deserve attention and warrants the protection afforded by ECR. Whether this extends to considering only the top slab longitudinal bars, A1 bars and J3 bars, or further considering the J4 bars or bottom slab bars or longitudinal bars in the exterior walls and the bottom slab is undecided. (These lower remaining bars could remain uncoated.)

It is not the intent to encourage the use of ECR but to inform the designer of its requirements for use in culverts and to address and answer questions asked in the past. In special instances, knowing when to use ECR and the complications for its use when considered may provide for a more educated Core Team decision. For further guidance on the use of ECR in concrete box culverts, contact the Bridge Division.

5.8 Extending SBCs and Use of Collars

The Standard Plans shall be used for extending SBCs when applicable. The quantities program *Single Box Culvert Quantities LRFD* should be used to estimate concrete and steel quantities. Use the help guide included with the program for instructions related to data input and output interpretation for these special type structures for plan reporting pay item quantities on the Roadway Plans.

A transverse joint is not required when extending the barrel not more than 15 feet. When concrete box culvert extensions exceed 15 feet, transverse joint requirements are the same as those for new culverts. See EPG 751.8.3.1 Joints.

Cutting details are provided in Standard Plans 703.38. It states “The box extension opening shall be built to match the existing box opening. When the existing opening does not match a size from the tables, the next larger size shall be used for determining the member sizes and reinforcement.”

Collar details are provided in Standard Plans 604.40 for attaching a single box culvert to a pipe but only for discrete single box culvert openings that are no larger than a 3 feet x 3 feet. For details of collars for an opening not shown in the Standard Plans, contact the Bridge Division.

Collars are not required for adjoining a new box culvert extension to an existing box culvert. This type of box-to-box culvert extension uses the existing ‘cleaned’ steel reinforcement and extends it into new concrete.
For unique situations where either the cutting details provided in the Standard Plans do not apply, for example, where an existing headwall or wingwalls be used-in-place, or where a collar may provide stability in weaker soils or a connection for adjoining different openings, contact the Bridge Division.

5.9 Gabion Baskets at Culvert Ends

See EPG 750.6.5 Erosion Control at Culvert Outlets – General Criteria for guidance.

This is not a standard item for SBCs but may be included if erosion is anticipated based on a history at that location, downstream effects indicate probable erosion event or stream velocity through and at the end of the culvert indicate probable event. Decision to use gabion baskets should also be based on Core Team authority and if approved for use the details of which shall be included on the Roadway Plans. Quantities and pay items for including gabion baskets at the ends are at the discretion of the districts.

Gabions should be placed immediately adjacent to and full width of the end of the bottom slab if used. Placement of gabions along the outside face of exterior wing walls is at the discretion of the districts and the highway designer. Bridge Maintenance in the past has expressed that this type of erosion control could be effective.

5.10 The "People Box" - SBC

Consideration should be given to special waterproofing or non-corrosive water stops for watertight construction joints. Contact the Bridge Division for guidance. Sometimes they can be used for cattle crossings.

5.11 Precast Concrete Box Culverts

All MoDOT cast-in-place concrete box culverts are allowed to be constructed using alternate precast concrete box culvert sections in accordance with Standard Specifications for Highway Construction Sec 733 unless otherwise noted on the Roadway Plans. Bridge Division has requested on the Bridge Plans in the past that in certain instances a box culvert shall be constructed using precast concrete box culvert sections because of an accelerated timeline for construction. This practice is available to districts but generally in the past has not been exercised most likely because of the presumption that the contractor would always choose the least cost/least time option. Realizing that this may not be true all of the time and with Core Team consensus, the precast alternate may be made required and shall be noted on the Roadway Plans. Pay items and quantities shall remain unchanged from those typically used for a cast-in-place concrete SBC.

Where a precast concrete box culvert could be used as a pedestrian box (or "people box") for walk-through or bicycle path, having multiple joints typically spaced at not less than 6 feet may be undesirable due to tripping hazards, ponding/freezing (settlement of many smaller length sections) or uncomfortable riding surface. Consideration should also be given to special waterproofing or non-corrosive water stops for watertight construction joints. Contact the Bridge Division for guidance.

The location of the first transvers joint beyond the headwalls is limited to 3'-0" which matches the culvert quantities software programs and a note that is stated on the Standard Plans for concrete box culverts (*See Part 3.5*). However, at this time, Standard Specifications Section 1049 still shows that the minimum barrel length for an end section is 2'-0". (Therefore, a note is required on any cast-in-place culvert plan sheet changing this minimum length to 3'-0" for end sections.)