South Carolina
Department of Transportation

PRECONSTRUCTION DESIGN MEMORANDUM

MEMO: PCDM-05

SUBJECT: Culvert Pipe Structural Design Criteria for SCDOT Fill Height Tables

DATE: January 29, 2021

RE: SC-M-714 and Standard Drawings 714-XXX-XX

This memorandum outlines the structural design criteria and process for determining fill height limits for the permanent culvert pipe types used by SCDOT. The following parameters are based on the AASHTO LRFD Bridge Design Specification (most current edition adopted by the Department) hereinafter referred to as "AASHTO LRFD", the SCDOT Supplemental Technical Specification SC-M-714, and corresponding AASHTO and ASTM material specifications. The intention of this design memorandum is to develop fill height tables for each pipe material that incorporate comprehensive design calculations in accordance with available AASHTO methodologies.

All Pipes – Submittals:

- Provide paper copies of detailed calculations signed and sealed by a Professional Engineer Licensed in the state of South Carolina.
- Provide electronic copies of these detailed calculations (Excel, MathCad, or other format) for each pipe configuration.
- Provide a summary fill height table showing pipe diameter and most conservative case (lowest fill height) results for each pipe gage or class in the format shown on SCDOT Standard Drawings. Provide similar tables for any non-circular pipe for future use.

All Pipes – Structural Design Criteria:

All buried pipe structures shall be designed according to the appropriate methods specified in the AASHTO LRFD Section 12. All buried pipes must be able to resist the factored loads given by the load combinations specified in AASHTO LRFD Section 12 (Service Limit State and Strength Limit State). According to the Definitions listed in AASHTO LRFD Section 1, the applicable Limit States are defined as follows:

- **Service Limit States** – *Limit states relating to stress, deformation, and cracking under regular operating conditions.*

- **Strength Limit States** – *Limit states relating to strength and stability during the design life.*

Post Office Box 191
Columbia, South Carolina 29202-0191

Phone: (803) 737-2314
TTY: (803) 737-3870

All Pipes – Soil/Structure Interaction:
For bedding and backfill, use materials conforming to the following classifications:

1. Well graded A-1 (AASHTO M 145) soils
2. Screenings meeting A-1 (AASHTO M 145)
3. Macadam or Marine Limestone Graded aggregate base from Qualified Product List 2
4. Materials meeting AASHTO soil classifications A-2-4.
5. Uniformly graded, coarse grained A-3 (AASHTO M 145) soils
6. Uniformly graded angular stone as large as #5 stone (Class 2 wrapped, vibrated)

Calculations should be based on 95% compaction of soil in bedding and structural backfill.

To produce the fill height tables, use the design calculations that yield the lowest fill height for each pipe and load case (i.e. use the most conservative soil – structure combination that is in conformance with SCDOT specification).

All Pipes – Physical Properties:
In each set of calculations for pipe, clearly indicate pipe physical properties including, weight (lb/ft), cross sectional area {gross & effective} (in^2), moment of inertia (in^4), radius of gyration (in), modulus of elasticity (lb/in^2), actual hydraulic area (ft^2), and Manning's roughness coefficient "n".

All Pipes – Joint Implications:
For pipe joints (tongues & grooves, coupling bands, etc.) if structural capacity (fill height) of pipe is reduced at connection, this data should be shown in the calculations and final fill height tables or alternate connections that do not reduce capacity should be provided for inclusion on SCDOT Standard Drawings.

For connections of pipe to drainage structures (interfaces with junction boxes, catch basins, manholes, etc.) if structural capacity (fill height) of pipe is reduced at connection, this data should be shown in the calculations and final fill height tables or alternate connections that do not reduce capacity should be provided for inclusion on SCDOT Standard Drawings.

All Pipes – Flexible Pavement:
Minimum flexible pavement depth (used on minimum depth calculations) should be 4" graded aggregate base with 2" asphalt surface course. (Note: Does not apply to Load Case 8, listed below.)

All Pipes - Loading Criteria:

The loads used for designing all buried pipe structures shall be performed according to AASHTO LRFD Section 12. (Note: The unit weight of soil used for design calculations shall not be less than be 120 (lb/ft^3))

Case 1: HL-93 Live Load Maximum Cover (Ft)

HL-93 Live Load & Soil/Road Dead Load - Design for Maximum Burial Depth to be measured from the top of pipe to the top of finished grade as dimensioned on SCDOT Standard Drawings.

Case 2: HL-93 Live Load Minimum Cover (Ft)

HL-93 Live Load & Soil/Road Dead Load - Design for Minimum Cover as shown in AASHTO LRFD Section 12.

Case 3: 75 Kip per Axle Construction Loading Minimum Fill Height (Ft)

75 Kip Per Axle Construction Live Load & Soil Dead Load - Design for Minimum Burial Depth to be measured from the top of pipe to the top of temporary construction fill.

Case 4: Non-Residential Driveway (Light Commercial) (Ft)

Same structural design loading as Case 2 but minimum cover over pipe is not limited by AASHTO LRFD Section 12 Minimum Cover requirement. For this condition, SCDOT will permit pipe to be installed at a depth that is shallower than the AASHTO minimum. The value used for minimum cover will only be limited by the pipes structural capacity determined from the structural design. Use Case 2 for heavy commercial driveways.

Case 5: 150 Kip per Axle Construction Loading Minimum Fill Height (Not be listed on Standard Drawing) (Ft)

150 Kip Per Axle Construction Live Load & Soil Dead Load - Design for Minimum Burial Depth to be measured from the top of pipe to the top of temporary construction fill.

Case 6: HL-93 Live Load Maximum Fill Height with Hydrostatic pressure (Ft)

HL-93 Live Load, Soil/Road Dead Load, and Hydrostatic Pressure head of 2x pipe O.D. measured from the pipe invert - Design for Maximum Burial Depth to be measured from the top of pipe to the top of finished grade as dimensioned on SCDOT Standard Drawings when pipe is subjected to hydrostatic pressure.

Case 7: Pipe Handling (Not listed on Standard Drawing)

Weight, Placement, Flexibility Limit, or any other construction/handling loading that requires additional pipe strength.

Case 8: Existing Residential Driveway Maintenance (Standard Drawing 714-990-MO)

This load case only applies to existing residential driveways with pipe diameters' less than or equal to 30", and where the depth of the ditch does not exceed 5'.

Live Load for Existing Residential Driveway (Case 8)

Single Dual Wheel Axial (one lane) 4 kips per dual wheel (total of 8 kips per axle). Single Dual Tandem Axial (one lane) 8 kips per axle (total of 16 kips). Effect of Lane Load can be neglected

for Residential Driveway Live Load Calculations. (Direction of Vehicle Travel across/transverse to Pipe Centerline)

All Pipes – Limitations on Structural Criteria & Published Fill Height Tables:
All SCDOT published fill height tables are based on calculations performed by various pipe manufactures in accordance with SCDOT Supplemental Technical Specification SC-M-714, SCDOT Standard Drawings, AASHTO LRFD, and this Culvert Pipe Structural Design Criteria.

Custom Designed Pipe Culverts:
A custom design is required for all pipe culverts when the required installation depth exceeds the minimum or maximum fill height values shown on the corresponding Standard Drawing. All custom designed pipe culverts shall be designed in accordance with SCDOT Supplemental Technical Specification SC-M-714, SCDOT Standard Drawings, AASHTO LRFD, and this Culvert Pipe Structural Design Criteria regardless of the pipe type or size. The custom design may vary parameters such as reinforcement area, wall thickness/wall profile, gage, or structural backfill, provided that all of these parameters still meet or exceed those described in SC-M-714. For all custom designs, the engineer shall provide a structural detail sheet in the plans for each different (structural backfill, pipe size or type) installation, and the manufacturer shall clearly mark special designed pipe indicating it's bury depth and installation location. The structure sheet(s) provided in the plans shall include at a minimum a typical pipe cross section, installation locations, and installation requirements.

Custom pipe culvert design procedure:

1. Use SCDOT Standard Drawing fill height tables (where applicable) that are based on calculation procedures outlined in this document.

2. When pipe installations are outside of the limits of the SCDOT Standard Drawing fill height tables, the engineer of record shall provide pipe type and design calculations that are site specific and meet the minimum structural design criteria outlined in this document. Use standard AASHTO/ASTM pipe geometry and configuration if appropriate. Provide a detail sheet for designed pipe indicating the standard pipe properties, installation locations, and specific installation requirements for each pipe.

3. When standard AASHTO/ASTM pipe cannot meet site requirements, consult with pipe manufacturers to confirm that a pipe is available or can be manufactured to meet the minimum structural design criteria outlined in this document for the site specific loading. Provide a structural detail sheet for each custom pipe indicating its geometry, physical properties, installation location, and custom installation requirements. For these cases, alternates such as box culverts or bridges may be appropriate.

Structural Criteria for HDPE Pipe:

HDPE Materials:
HDPE Pipe in accordance with AASHTO M 294 Type S
Calculations submitted by each manufacturer since pipe geometry can vary between manufacturers.

HDPE Pipe Sizes to Evaluate (Only if available):
12, 15, 18, 24, 30, 36, 42, 48, 54, 60

HDPE Design Criteria:
AASHTO LRFD Section 12

Strength Limit State Design including:

- Wall Area
- Buckling
- Flexibility Limit

Service Limit State Design including:

- Deflection (5% maximum)

HDPE Notes:
Each manufacturing facility wishing to provide pipe for SCDOT projects must provide calculations or certify calculations before being listed on an SCDOT Qualified Product Listing for pipe.

Structural Criteria for RC Pipe:

RCP Materials:
RCP in accordance with AASHTO M 170 Class II, Wall B & C – Worst Case
RCP in accordance with AASHTO M 170 Class III, Wall B & C – Worst Case
RCP in accordance with AASHTO M 170 Class IV, Wall B & C – Worst Case
RCP in accordance with AASHTO M 170 Class V, Wall B & C – Worst Case
Note: "A" wall pipe is not manufactured for SCDOT therefore calculations are not be required for "A" wall pipe.
Elliptical Reinforced Concrete in accordance with AASHTO M 207 (For Custom Designs)
*Reinforced Concrete Pipe Arch in accordance with ASTM C 506
*Note: For Custom Designs, Designer must verify the availability of Arch Pipe before this Option can be selected.

Concrete Compressive Strength of SCDOT Class 4000P minimum & AASHTO M170 (latest edition).

Reinforcement shall consist of wire fabric conforming to AASHTO M 336 or of bars conforming to AASHTO M 31 Type W.

RCP Sizes to Evaluate (Only if available):
Circular sizes: 12, 15, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90, 96, 108, 120.

Non-circular sizes submitted by industry only if available.

All calculations and fill height values are based on the design requirements listed in AASHTO M 170 tables for each corresponding pipe class.

RCP Design Criteria:
AASHTO LRFD Section 12.

The structural design calculations must be prepared using either of the following methods:

- The Direct Design Method at the strength limit state as specified in AASHTO LRFD Section 12.

- The Indirect Design Method at the service limit state as specified in AASHTO LRFD Section 12.

RCP Notes:
Each manufacturing facility wishing to provide pipe for SCDOT projects must provide calculations.

Fill Height Table Structural Criteria for CAAP Pipe:

CAAP Materials:
CAAP in accordance with AASHTO M 196, 16 gage
CAAP in accordance with AASHTO M 196, 14 gage
CAAP in accordance with AASHTO M 196, 12 gage
CAAP in accordance with AASHTO M 196, 10 gage
CAAP in accordance with AASHTO M 196, 8 gage
CAAP pipe arch in accordance with AASHTO M 196, 16 gage
CAAP pipe arch in accordance with AASHTO M 196, 14 gage
CAAP pipe arch in accordance with AASHTO M 196, 12 gage
CAAP pipe arch in accordance with AASHTO M 196, 10 gage
CAAP pipe arch in accordance with AASHTO M 196, 8 gage
Aluminum Alloy Sheet conforming to AASHTO M 197 Alclad 3004-H32 Alloy

Calculations submitted by each manufacturer since pipe geometry can vary between manufacturers.

CAAP Sizes to Evaluate (Only if available):
2-2/3"x ½" Corrugation for 12, 15, 18, 24 Only
3"x1" Corrugation 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90, 96, 108, 120
Non-circular sizes submitted by industry only if available

CAAP Design Criteria:
AASHTO LRFD Section 12.

Strength Limit State Design including:

- Wall Area
- Buckling
- Flexibility Factor
- Seam Failure

Service Limit State Design including:

- Deflection (5% maximum)

CAAP Notes:
Each manufacturing facility wishing to provide pipe for SCDOT projects must provide calculations or certify calculations before being listed on an SCDOT Qualified Product Listing for pipe.

Structural Criteria for SRAP Pipe:

SRAP Materials:
SRAP in accordance with AASHTO M 196, 16 gage
SRAP in accordance with AASHTO M 196, 14 gage
SRAP in accordance with AASHTO M 196, 12 gage
SRAP in accordance with AASHTO M 196, 10 gage
Aluminum Alloy Sheet conforming to AASHTO M 197 Alclad 3004-H32 Alloy
Calculations submitted by each manufacturer since pipe geometry can vary between manufacturers.

SRAP Sizes to Evaluate (Only if available):
12, 15, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90, 96, 108, 120

SRAP Design Criteria:
AASHTO LRFD Section 12.

Strength Limit State Design including:

- Wall Area
- Buckling
- Flexibility Factor
- Seam Failure

Service Limit State Design including:

- Deflection (5% maximum)

SRAP Notes:
Each manufacturing facility wishing to provide pipe for SCDOT projects must provide calculations or certify calculations before being listed on an SCDOT Qualified Product Listing pipe.

George R. Bedenbaugh, Jr.

George R. Bedenbaugh, Jr.
Preconstruction Support Engineer

January 2021 Letting

Effective Date

GRB
ec:
John Boylston, Director of Preconstruction
Robbie Isgett, Director of Construction
David Cook, Director of Maintenance
Rob Perry, Director of Traffic Engineering
Chris Gaskins, Design Build Engineer
David Rister, Director of Mega Projects
Jennifer Necker, RP Engineer – Lowcountry
Leah Quattlebaum, RP Engineer - Pee Dee
Philip Sandel, RP Engineer - Midlands
Julie Barker, RP Engineer - Upstate
Tad Kitowicz, FHWA

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