Structural Design Considerations for Specifying Thermoplastic Pipe

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Overview

Selection of pipe material type for culverts and drains should include consideration of structural design, hydraulics, material availability, durability, and cost. The purpose of this document is to outline structural design considerations that should be made when specifying thermoplastic pipe culverts and storm drains. Structurally, properly specified and installed pipe can be expected to perform as well as other pipe type installations used for parallel drainage, cross-drainage, and storm drain situations. These design considerations are not intended for pipe underdrains covered in Item 556 of the TxDOT specifications.

Thermoplastic pipe is considered a flexible pipe and proper construction installation is critical to ensure expected performance. A flexible pipe installation structurally relies on the surrounding trench, bedding, and the pipe structural backfill and thus, if any of these are deficient, the pipe installation could result in an unacceptable performance.

Current TxDOT Specifications allow for thermoplastic pipe culverts and drains up to 48 inches in diameter with fill depths up to the depth approved for the pipe type and backfill conditions noted on the approved products list.

Materials

Current TxDOT specifications include both High Density Polyethylene (HDPE) and Polypropylene (PP) materials for use as pipe culverts and storm drains. DMS-4710, “Thermoplastic Pipes, Joints, and Fittings” exists to ensure consistent criteria for qualifying pipe products on an approved products list jointly managed by Materials and Test Division and Bridge Division. The pipe products are required to meet conformance criteria of AASHTO National Transportation Product Evaluation Program (NTPEP) Committee Work Plan for Evaluation of Manufacturers of the submitted thermoplastic drainage materials. Each material supplier is required to submit durability and design information for inclusion of products on the Material Producer List (MPL). A designer should be aware of this information when specifying thermoplastic pipe. A corrugated dual wall pipe with a smooth interior is required. Both HDPE and PP pipes perform similarly in the finished installation, and it may be that both products are acceptable for a given situation, though there are differences in the products that should be understood when specifying thermoplastic pipe. Typically, PP pipes are stiffer than HDPE pipes which provide for more resilience against installation related deflection and is preferred for use over HDPE on transportation projects.

The typical fabricated joint length of pipe is 20 feet. Cutting the pipe in the field is often required to fit the design situation.

A soil-tight joint is the default type of joint per current special specification. Soil-tight joints are typical for other pipe types. Watertight joints can be provided, typically without a cost increase and offer a more resilient performance compared to soil-tight joints. In cases where the water table is above the bottom of the pipe and when pipes are placed in environmentally sensitive areas, specify a watertight joint. Include a note in the plans, as applicable, to require watertight joints.

Site Condition

The existing soil characteristics and the installation process of thermoplastic pipe significantly contributes to the performance of the product. Consideration of the geologic condition or subsurface conditions is important when considering use of plastic pipe. Particularly, the following conditions can pose significant issues during construction and may result in long term performance issues:

- Unstable earth: Thermoplastic pipe is required to be installed in a trench with a minimum depth of one foot above the pipe. Stable earth materials are required to be under the pipe as a foundation as well perform as vertical trench walls. Additional trench excavation may be required if a stable foundation is not found. If the trench walls slough during construction because of unstable material, a contractor would need to take measures to provide a stable, vertical trench wall. Design engineers specifying plastic pipe must have knowledge of local soil types and consider the presence of poor native soils when specifying trench width or pipe stiffness. Poor native soils include poorly compacted soils with blow counts of ten or less, muck, highly expansive soils, or poorly compacted fills. The minimum trench width called for in the current specifications assumes that the native soil is able to sustain a vertical cut and must be increased for poor soils. Pipe stiffness requirements beyond those in AASHTO M294 must be indicated on plan sheets.
- Water table is above the bottom of the pipe: Because thermoplastic pipe is a lightweight material, it is more prone to buoyant forces moving it when installed below a water table. More detailed design information related to dewatering requirements and final pipe installation configuration is required when a water table is present. Where groundwater and fully saturated soil conditions are anticipated, a minimum of 4 feet of cover for a storm drain outside the roadway should

be considered or otherwise designed. For locations where a storm drain is under a roadway, the required minimum 1 foot subgrade cover specified may be sufficient, but the specifying engineer is responsible to confirm this. The risk of high groundwater conditions must be considered and soil borings should be taken when necessary to determine depth to groundwater. Generally, plastic pipe should be avoided in areas where the water table is above the bottom of the pipe.

- Rocky earth: The presence of large rocks in the earth at the pipe location can cause issues that need to be addressed. A rocky jagged trench bed requires additional bedding to prevent potential point loads on the pipe. Excavating large rocks when creating the trench may require additional effort to construct vertical trench walls.

Pipe Design

Thermoplastic pipes are generally suitable alternatives for other type of pipes. However, some conditions may require a rigid pipe. A "Thermoplastic Pipe Installation" detail sheet must be included in the plans when thermoplastic pipe is specified. A working drawing is available that may be used and modified for the project conditions. This drawing provides some general guidance for use. The specifying professional engineer is required to confirm the conditions for the project and structural adequacy of the pipe system.

The Plastic Pipe Institute publishes an online design manual that contains information related to all aspects of design and construction of thermoplastic pipe. See Chapter 7 of the Plastic Pipe Drainage Handbook (plasticpipe.org) for structural design of plastic pipe systems. Additionally, vendors of the pipes also have information on the use of their products.

When specifying plastic pipe on a project, the specifying design engineer must be aware of minimum depth of fill required and how these are measured for different pavement types as well as maximum depths permitted for the material specified on a project. Design engineer is responsible for ensuring that depth of fill is not less than 18" for pipe diameters up to 36" or 24" for pipe diameters over 36". The depth of fill is measured as the distance from the top of the pipe to the bottom of the flexible pavement, or from the top of the pipe to the top of rigid pavement.

Excavation and Backfill

Trench excavation is required for pipe installation. Designer must include Item 402, "Trench Excavation Protection" when necessary.

As a flexible pipe, thermoplastic pipe relies on the structural backfill for rigidity and performance. One of the following materials must be specified as the pipe structural backfill (See Thermoplastic Pipe Installation Working Drawing):

- Granular Backfill: Hard, durable, clean granular material that is free of organic matter, clay lumps, and other deleterious matter meeting Table 1. Note that if a granular backfill is used, a geotextile filter fabric must be placed against the native material and on top of the backfill to prevent fines from migrating into the fill, which could result in embankment settlement. Filter fabric may be omitted if a boring within 500 ft of the pipe indicates that the native material has minimal fines content or low risk of water infiltration.
- Cement Stabilized Backfill: Backfill per Article 400.3.3.4 in the Standard Specifications.
- Flowable Backfill: Flowable backfill per Item 401, "Flowable Backfill" of the Standard Specifications. When specifying flowable backfill as the structural backfill, the pipe should be expected to experience buoyant forces during backfill placement. As such, details for pipe restraint is required to be included in the plans. Otherwise, include plans notes and staged placement details requiring that the backfill be placed in lifts and allowed to set prior to placing next lift. Flowable backfills can be designed to set rapidly allowing for expedited construction, but generally, time must be apportioned appropriately when a standard flowable fill is used and pipe is not restrained. Specify "Excavatable" type flowable fill for structural backfill around a pipe to accommodate for settlement without damaging the pipe.

Trench excavation and structural backfill are not subsidiary to the pipe item of work. Separate pay items area required. Include Item 400, "Excavation and Backfill for Structures," for measurement and payment of the trench excavation, bedding, and pipe structural backfill. If flowable backfill is specified both Item 400 and Item 401 are required. The backfill above the structural backfill, identified as "Final Backfill," may consist of the same material as structural backfill, but may also utilize other backfill materials, such as the native material or embankment material. Specify what material is to be used and how it is measured and paid for. Use pay Items 0400 60XX STRUCT EXCAV (PIPE) (GRANULAR BKFL), 0400 60XX STRUCT EXCAV (PIPE) (CEM STAB BKFL), or 0400 6003 STRUCT EXCAV (PIPE) and 0401 6001 FLOWABLE BACKFILL.

Gradation Requirements for Granular Backfill Material

Sieve Size	Percent Retained (Cumulative)
1 in.	0-5
7/8 in.	0-35
1/2 in.	0-75
3/8 in.	0-95
No. 4	35-100
No. 10	50-100
No. 200	90-100

Table 1. Granular Backfill Gradation

Construction Loading

TxDOT Specifications for all pipe types (Corrugated Metal Pipe, Reinforced Concrete Pipe, and Thermoplastic Pipe) requires a minimum of 4 ft of permanent or temporary compacted fill be in place prior to operating heavy earth-moving equipment to haul over the the structure, unless otherwise shown on the plans or permitted in writing. PPI publishes design guidance that can be used by an engineer to evaluate minimum depth of fill for different pipe diameters and construction loads.

Concrete End Treatments

Concrete end treatments are required at each exposed end of a thermoplastic pipe to protect the pipe from fire and mechanical damage. The end treatment must consist of a concrete headwall, concrete wingwalls, and a concrete apron. Precast or cast-in-place end treatments may be utilized. Rock riprap is not a suitable apron adjacent to the end of pipe.

Plan Detailing Information

For large projects, with varying conditions, and multiple runs of plastic pipe, the following information should be tabulated on plan sheets:

Pipe Type (PP/HDPE)	Size	Station Limits From	Station Limits To	Backfill Material Required	Backfill Height (ft)	High Water Table Conditions

Material Producer List

TxDOT's Material Producer List for thermoplastic pipe includes maximum fill depth by backfill type. The current version of the prequalified producers is available here: https://www.txdot.gov/business/resources/materials/material-producer-list.html

Plastic Pipe When Proposed as a Contractor's Alternate

When thermoplastic pipe is submitted as an alternate to reinforced concrete or corrugated metal pipe, thermoplastic pipe must meet the requirements of the most recent construction specifications and DMS-4710. As discussed in this document, proper use and installation of thermoplastic pipe can be expected to provide a durable drainage structure. However, acceptance or denial of a proposed alternate is at the sole discretion of the Engineer and the contractor's request should be accompanied by sufficient documentation addressing the demands of the location the pipe is to be installed. Impacts to the project schedule and any additional costs resulting from the use of alternates are the sole responsibility of the contractor. It should be conveyed to the contractor that there will be a review period not to exceed thirty days. Inclusion of plastic pipe as an alternate may be approved in accordance with standard contract management procedures. Once conceptually approved, contractor's proposed changes must be

in accordance with this design guidance document and related plan revisions must be signed and sealed by a licensed Engineer. The final as-built plans should include the new design sheets. The contractor's submittal is expected to include the following:

1-Redlined set of drainage plans reflecting the revised locations.

2-Certification that the use of the plastic pipe and proposed bedding are adequate for the proposed application, depth, etc.

3-Provide a completed thermoplastic pipe installation drawing using TxDOT working drawings which may be found at: (https://ftp.txdot.gov/pub/txdot/brg/thermoplastic-pipe-installation-drawing.pdf, https://ftp.txdot.gov/pub/txdot/brg/thermoplastic-pipe-installation-drawing.dgn)

The contract should be changed to reflect the work is in accordance with Special Specification 4216 or latest thermoplastic pipe special specification at time of letting. Minimum values, such as cover depth, required by the specification, installation drawing, etc. will not be waived. Use granular backfill unless flowable fill or CSB is required by the alternate design. When the contract drawing shows flowable fill or CSB as the pipe backfill, that must be enforced as part of the alternate design per the bid plans.