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Literature Search on Use of Flexible Pipes in Highway Engineering for DOTD's Needs

INTRODUCTION

The Louisiana Department of Transportation and Development (DOTD), through the Louisiana Standard Specifications of Roads and Bridges, gives a thorough guideline to what is required for the implementation of pipes for culverts and storm drains. The design procedures, design criteria, and implementation process for plastic pipes has been widely investigated, thus the use of plastic pipes for various types of drains is becoming more popular and adopted by several states around the United States.

This report presents the requirements and specifications for the use of concrete and plastic pipes in Louisiana and nearby states, discusses the research completed in recent years regarding the design procedures and acceptance criteria for the use of plastic pipes for storm drains and culverts, and provides details of the current practice and adoption of other state departments of transportation. Additionally, a comparison between the implementation of concrete versus plastic pipes, and recommendations of when plastic pipes should be used for the different drainage applications in transportation projects is included.

OBJECTIVE

The overarching research objective was to determine where, when, and how DOTD can use plastic pipes. The long-term goal is to include plastic pipes into the DOTD materials specifications such that it is an option for engineers, designers, and contractors.

SCOPE

Drainage in Louisiana transportation projects is a critical component in pavement infrastructure and is typically addressed using rigid concrete pipes. Plastic pipes include many various polymer-based materials (e.g., high-density polyethylene (HDPE), polyvinyl chloride (PVC), and polypropylene (PP)). A long-term track record of rigid concrete pipe performance is available to DOTD, but limited information is available on plastic pipes. A better understanding of the applications, limitations, and advantages of plastic pipes can help DOTD facilitate the design, construction, and maintenance of pavement infrastructure beyond traditional methods.

METHODOLOGY

The specific aims for the report included the following:

- Provide a historical summary of the DOTD specifications for culverts and storm drains to document the criteria for making decisions in pipe selections. The outcome of this task is to provide a baseline of what was previously recommended and what criteria are important in drainage applications.
- Synthesize the current literature on plastic pipe research from Louisiana and other states and various National Cooperative Highway Research Program (NCHRP) reports. This task involves a comprehensive literature review on plastic pipes and their application to transportation drainage systems.
- Survey other state DOTs with similar soils, environments, and situations. This task involves state-of-practice for other DOT agencies. For example, practices at Texas, Kansas, Minnesota, Alabama, Illinois, Georgia, and Florida were investigated.
- Compare performance of concrete and plastic pipes, along with associated installation requirements. The comparison will be made in terms of plastic and rigid pipe

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dimensions, cover, bedding, backfill, structural capacity and loading criteria, transportation to the site, QA/QC inspection procedure, service life, application, excavation geometry, maintenance, and all the make and models of plastic pipes.
- Provide recommendations for DOTD on where and when to allow the use of each type of plastic pipe in drainage applications, required installation procedures, and limitations associated with plastic pipes.

CONCLUSIONS

A review of DOTD and other state agency specifications were performed to define how plastic pipes have been introduced and how they vary across the U.S. The report summarizes and compares the specifications of concrete and plastic pipes for DOTD, along with how they changed from the last specification version to the most recent 2016 version. These specifications for plastic pipes are in line with other state agencies and AASHTO and ASTM specifications.

To compare concrete and plastic pipes, the same design service life can be estimated assuming deflection criteria are met for plastic pipes. The most incidental differences between plastic and concrete pipes are installation times and product weights. The installation rate of plastic pipes is more than 2 times faster than reinforced concrete pipes. Considering pipe diameters from 4 to 15 in., plastic pipes weight ranges from 7 to 60 lb/ft. For the same diameters, reinforced concrete pipes weight ranges from 15 to 120 lb/ft, which approximately doubles the plastic pipes weights. This is expected to affect installation costs as smaller equipment can be used for plastic pipes and could potentially be used for less time.

For all the considered plastic material pipes, the deflection value is lower than the allowable when using the initial modulus of pipe material. When using the long-term modulus value, the deflection increases towards the limits of compressive strain for both HDPE and PP pipes. In particular, the results of these example calculations are in accordance with the evaluation of HDPE pipes made by Abolmaali et al., which show long-term damage, especially excessive deformation in Houston, Texas. Based on Abolmaali et al. (2010), inspections using a high-intensity lighting inspection camera can be used to determine the failure mode and deformations can be quantified using a pipeline laser profiling unit.

DOTD specifications provide guidance for the appropriate implementation of thermoplastic pipes used for cross drains, side drains, and storm drains that follows the state-of-practice. Several Engineering Directives and Standards (EDSM) and BM-01 Standard Plans summarize the most relevant aspects of the DOTD specifications and provide additional insight for the use in the field. EDSM II.2.1.1 states that a 70-year design life can be used for highways ordinarily requiring 50-year design life if the fill height on the cross drain is greater than 10 ft. Florida DOT has implemented 100-year design life for polypropylene (PP) pipe if the extensive requirements in their specifications are met, which are based on slow crack growth resistance testing and tests to verify that the anti-oxidant package would last longer than the desired design life. In addition, FDOT has also implemented similar testing for 100-year design life HDPE pipe. Other states, such as Texas, Kansas, and Minnesota, also permit PP to be used in cross-drain applications, but they impose ADT limits (Texas < 2000, Kansas < 3000, and Minnesota < 5000). As a result, the outcome of this survey of other state agencies indicates that PP pipe can be used in Louisiana as outlined in the next version of EDSM guidelines (in preparation), where PP is allowed to replace corrugated polyethylene pipe double wall (CPEPDW). CPEPDW is currently used for cross drain (service life of 50 years) and side drains (service life 30 years except for bridge drains that are 50 years), where the traffic volume is less than 3,000. The service life should remain at the current design life of 30 years or 50 years as promulgated in the EDSM specifications. If a longer service life is considered, the testing protocol should follow Florida DOT because it uses stress crack resistance and antioxidant depletion for evaluating long-term performance. Field performance documentation is also necessary to substantiate post-installation and long-term performance.

The PP pipe modulus reduces drastically from initial to long-term conditions (84% reduction) and the deflection increases ~2.4 times. The PVC pipe modulus reduces only 66% and the deflection increases ~1.4 times. PP and PE materials have similar results as PE pipe modulus reduces 81% but the deflection is increased by ~2.5 times. These design values and calculations can help to grasp how the different pipe materials might perform in practice but experimental (field and laboratory) data is advised.

RECOMMENDATIONS

To facilitate and fast track the implementation of PP pipe with DOTD engineers, a track record of proven performance may be required through demonstration project(s). An example demonstration project involves a low-volume road (ADT < 3000), where the PP pipe is installed, instrumented, and monitored to evaluate its efficacy with other plastic pipes. In particular, a demonstration project specifically focused on the cross drain application could be more valuable for DOTD engineers because a major focus of cross drains is the dip that may form over the roadway. Demonstrating that the dip is limited and performance is satisfactory will assist DOTD in considering and selecting PP pipes as an alternative.

It is imperative to require post-installation and long-term inspections for plastic pipe, especially for projects that include HDPE and PP. This will provide feedback to the design engineers at DOTD on performance.

An additional recommendation stemming from this literature review was the lack of documented field performance for plastic pipes in Louisiana. Beyond specifications and design life, quantifying field performance will be beneficial when deciding which type of pipe to use.