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Assessments of Gravity Pipe Systems – Initial Pipe Cost not the Primary Consideration

Engineers are facing budgetary challenges especially in the current recession. Designing and building infrastructure to stay within budgets becomes the primary focus and municipal and consulting engineers can lose sight of project life and serviceability expectations.

This is particularly true when it comes to gravity pipe storm drainage systems and sanitary sewers. Too often decisions are based on the initial cost of the pipe and not enough consideration is given to the cost of proper installation, maintenance or rehabilitation costs and service life.

Municipalities should conduct assessments of the various gravity pipe systems that are available. It is important to distinguish between the terms “pipe systems” and “pipe materials”. Pipe systems include the pipe material, couplings or joints, fittings, connections to maintenance holes, and embedment materials. A thorough pipe assessment will examine the following key issues:

- Technical
- Financial
- Risk

Technical Assessment

Specifications and Standards: A technical assessment examines the specifications and standards that are being referenced in the contract documents. Typical standards and specifications are produced by agencies such as Canadian Standards Association and Ontario Provincial Standards. A particular manufacturing standard will often reference a standard for a test method or an installation standard. For example, *OPSS 1840 - MATERIAL SPECIFICATION FOR NON-PRESSURE POLYETHYLENE PLASTIC PIPE PRODUCTS* includes references to *AASHTO M 294 Standard Specification for Corrugated Polyethylene Pipe, 300 to 1500-mm Diameter* and *ASTM F894 - 07 Standard Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe.* These standards subsequently reference *AASHTO Section 30* and *ASTM D2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.*

ASTM D2321 references the engineer or his/her authorized representative on site 33 times and makes him/her responsible for issues such as:

- Trench widths
- Embedment densities
- Unstable trench bottoms
- Minimum cover for construction loads
- Field monitoring
- Establishing methods for controlling and monitoring distortions of pipe
- Connections to manholes

Engineers need to fully understand the ramifications of the entire referenced standard such as in the example above.

Quality Control: The engineer should establish what quality control programs are in place by a particular industry to ensure that the quality of the product produced and shipped to site is the quality that the engineer expected when he/she specified the pipe material. In Ontario all concrete pipe is produced at plants that are prequalified under the Plant Prequalification Program for precast concrete drainage products. The Plant Prequalification Program covers

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all concrete pipe, concrete maintenance holes, catch basins and fittings. *OPSS 1820 Material Specification for Circular Concrete Pipe* requires manufacturers of circular concrete pipe to possess a current Prequalification Certificate issued under the Plant Prequalification Program.

Structural Design: A structural failure of a culvert will result in a collapse of the highway pavement. Structural failures are usually very sudden with no warning to drivers using the highway.

There are significant differences between how a rigid concrete pipe and a flexible plastic or flexible steel pipe function. It is imperative that engineers fully understand how a rigid pipe system such as reinforced concrete pipe functions and how a flexible pipe system such as CSP or plastic PVC or HDPE functions; furthermore, engineers must understand the differences between the two systems. Without a proper understanding of gravity pipe systems, engineers may prepare inadequate material, installation and testing specifications that ultimately result in premature maintenance or failures of the systems. Additionally, engineers need to understand proper installation practices for both systems.

Ontario Provincial Standard Specification (OPSS) 410 states *"Flexible Pipe means pipe that can deflect 2% or more without cracking, such as polyvinyl chloride or polyethylene or steel pipe."* They have little inherent strength and depend upon a properly installed and compacted soil embedment to achieve the required design strength. A flexible pipe installation will typically receive less than 10% of the design strength from the pipe itself with the remainder being provided by the soil embedment around the pipe. Loss of the embedment due to washout or infiltration into the pipe due to leaky joints or corroded pipe walls will cause the pipe to collapse.

OPSS 514 ***CONSTRUCTION SPECIFICATION FOR TRENCHING, BACKFILLING, AND COMPACTING*** states: *"Bedding material placed in the haunches must be compacted prior to continued placement of cover material. Bedding requiring compacting shall be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted to 95% of the maximum dry density before a subsequent layer is placed. Bedding on each side of the pipe shall be completed simultaneously. At no time shall the levels on each side differ by more than the 200 mm uncompacted layer."*

OPSS 410.07.16.05 states: *"Ring deflection testing shall be performed on all pipe sewers constructed using plastic pipe".* Engineers should always insist on deflection testing of the flexible pipe systems after installation. This is usually done by manually pulling a deflection gauge or mandrel through the pipe. Deflection testing should be carried out no sooner than 30 days after the soil over the pipe has been installed to final grade. Some municipalities, such as the City of Hamilton and the Region of Niagara, require a second test prior to final acceptance. This is a very good practice.

Rigid pipes will crack before they are deflected 2%. They have inherent pipe strength. Rigid pipes receive additional support from the bedding cradle underneath the pipe when they are installed. Reinforced concrete pipe design has traditionally been very conservative and concrete pipes are regularly overdesigned. A concrete pipe will usually provide more than 60% of the required structural strength with the remainder provided by the soil embedment. Regularly all or almost all of the design strength is built into the pipe itself. As an example a 50D pipe would be acceptable for a particular design but the engineer may specify 100D or 140D.

Water-Tightness and Joints: The type of joints available and the water tightness of the system can have a major impact on the structural stability of the system.

Hydraulics: The technical assessment should include an examination of the factors affecting hydraulics such as the Mannings 'n' factor of the pipe, actual inside diameter, deflection of a flexible pipe and corrugation growth in externally corrugated plastic pipe products. If a culvert fails to perform as required as a conduit due to deflection, clogging or other factors, catastrophic failures can occur. Failures include a complete washout of the culvert or washout of the embedment soils around the culverts which in turn causes a collapse of the culvert pipe and the pavement overhead.

Financial Assessment

Cost of Supply: Initial pipe cost should be considered in a financial assessment but the engineer is cautioned not to limit his or her decision solely to initial costs.

Cost of Proper Installation: Proper installation is essential especially in regards to flexible pipe systems as flexible pipe systems require approved embedment materials, appropriate trench widths and the correct level of compaction completely around and over the pipe.

Maintenance Costs: What maintenance costs, if any, are anticipated over the life of the project? How do maintenance costs affect the initial pipe material choice?

Service Life versus Project Life: The engineer needs to decide what the expected life of the project is and then assess the available pipe materials to determine which products have a service life that equals or exceeds the project life.

Risk Assessment

Modes of Failure: A risk assessment should look at the different modes of failures of the available pipe products. The different modes of failure include:

- Buckling due to poor installation of flexible pipes
- Corrosion of steel
- Combustion of plastic
- Disjointing
- Flotation
- Wash-out
- Abrasion
- Post installation connections
- Chemical attack

The best risk analysis is to examine the track record of a particular product and evaluate how well it has performed in similar applications with similar heights of cover and traffic loads.

Additionally, installing gravity pipe in trenches where the use of a trench box or sheet piling is required by the Department of Labour poses challenges for the engineer and the contractor, especially in regards to the proper installation of flexible pipes. A future edition of the Concrete Pipe Journal will include an article addressing installation of gravity pipes in trenches.

Conclusions

Municipalities can start to protect themselves from litigation due to failures of gravity pipe drainage systems by conducting comprehensive assessments of the pipe systems that they are using.

Individual engineers can and should protect themselves by:

- Understanding rigid and flexible pipe design
- Requiring quality control programs for the manufacturing and testing of pipe and raw materials
- Writing thorough installation specifications
- Requiring post-installation inspections
- Addressing trenching and safety requirements

Ontario Concrete Pipe Association welcomes comments on this article.
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