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Estimated Material Service Life of Drainage Pipes

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When it comes to selecting different materials for pipe systems (i.e. sewers or culverts), the common choices are concrete, steel, and plastic. Each material has a history, and in terms of pipe applications, each carries a different track record for serviceability. "Serviceability" is defined as a period of time for which a product can service to function in its intended role. In the case of pipe systems used under our roadways, it would be the length of time that a sewer or culvert can function both as a conduit to carry water and a structure to support a roadway.

So what factors can affect the serviceability of a pipe? Factors considered by the Ministry of Transportation's Gravity Pipe Design Guideline (GPDG), Chapter 7, Durability Design Evaluation, which cause material degradation and/or affect product functionality include: pH Level; Soil and Water Resistivity; Acid, Chloride or Sulphate Corrosion; Electro-Chemical Corrosion of Steel; Slow Crack Growth and Oxidation of Thermoplastics; Abrasion; Fire Resistance.

These factors and others effectively determine the Estimated Material Service Life (EMSL) for a pipe. EMSL is defined as the number of years that a material, system or structure will provide satisfactory service before rehabilitation or replacement is necessary. The ministry's GPDG relates EMSL to product durability and attempts to quantify it. Understanding what each pipe material can provide for a service life is key in assessing how that pipe can function in the intended application. The expected service life for that application is then referred to as the Design Service Life (DSL).

Inherently, it can be expected that the DSL for a high volume highway would be a factor greater than the DSL for a low volume arterial road. The MTO uses DSL's of 25, 50 and 75 years depending on the application of highway facility, and the location of the sewer or culvert along the highway. When selecting a pipe material, the type of pipe whose EMSL more closely matches the application's DSL should offer a more cost-effective alternative when rehabilitation and/or replacement costs are considered. The exercise used to compare the present value of future costs is better known as Life Cycle Cost Analysis (LCCA). It's a balance of initial first costs, with the need for reliable long term performance and minimal future maintenance costs.

So how did the different values for EMSL of pipe come to be? Much of it is history and the experience taken from the field. A good starting point is the recommendations published by the US Army Corps of Engineers. It provides a list of serviceability expectations for pipe systems categorized by material type:

a) Concrete is 70-100 years;

b) Steel is at least 50 years;

c) Plastic is 50 years

However, caution to the user. Site conditions can change midstream, and never is one application the same. A good example is Ontario's aggressive environment. An article in Environmental Science & Engineering magazine (Nov. 2009) by the steel industry, recognized the significant impact that negative environmental conditions such as acid rain, air pollution and use of chlorides were having on the lifespan of highway drainage pipes. Impacts included corrosion of steel pipes that were expected to be protected by the pipes' surface coatings. One example cited in the article was the replacement of a CSP culvert where there was no invert remaining after being in place for only 19 years of service.

In MTO's GPDG, there are equations that can be used to project the EMSL of pipe materials. For concrete and steel, the statistical regression equations can appear intimidating and confusing, but their development is

partially substantiated by the history of installed pipes. For plastic pipe there are no such models since there is limited empirical data that can be used. Keep in mind, polyvinyl chloride (PVC) products for watermain and sewers were not fully engaged by manufacturing companies until the late 1960s. Other plastic materials for sewer pipe, like polyethylene and polypropylene, would still follow PVC in later years. The proven performance history of thermoplastic pipe is relatively short, just over 40 years. However, MTO takes the position in assuming an EMSL of 75 years.

According to information received in a freedom of information request of the MTO, a senior project engineer with MTO had this to say: “No research has been undertaken to establish criteria for establishing the EMSL for HDPE pipe for highway applications in Ontario. However, where the application requires a DSL of 75 years, post installation verification of the pipe integrity should be undertaken, such as by mandrel pull or video inspection and it should be verified that there are no unusual risk factors associated with the application. While Post Installation Inspection will be performed as per SP 104S02, only 25% of the pipes will be inspected”.

Since service life for thermoplastic pipe is still to be fully experienced, one would think the use of a “projected” EMSL in a changing environment could be risky. At the least, check 100% of installed pipes until field experience can support these projected values.

For concrete pipe, the industry has addressed the impacts of the environment. The concrete of five years ago is not the concrete of 50, 20 or even 10 years ago. Material development and new technologies provide greater durability and improved performance for today’s infrastructure projects. For example,

- Eliminating the deteriorating effects of sulphates in soils by using sulphate resistant cement or a cement/slag blends for sulphate resistant concrete;
- Minimizing the effects of physical weathering cycles (freeze-thaw conditions) by entraining air into the concrete;
- Reducing the chloride penetration potential from road salts by producing less porous concrete (or denser concrete).

Infrastructure has benefited from these and other advances in concrete. So where does the everyday designer or specifier start in order to select the “appropriate use” of pipe? Should pipe be chosen strictly for the environmental conditions in which pipe will exist? What about a factor not yet mentioned and which bears great influence on the DSL – the installation of the pipe. Most times, the pipe installation is overlooked when different pipe systems are considered. In theory, a pipe system is not only the pipe itself, but the entire pipe embedment. Therefore, the evaluation of a pipe system should include: the pipe material, the pipe installation method, and the intended post-installation performance of the pipe. To do this, a designer or specifier must understand the differences between rigid pipe and flexible pipe. A poor pipe design or an improper installation will cause a pipe system to fall short of the projected DSL, regardless if the pipe’s EMSL was to be realized.

In another freedom of information request, the same MTO regional engineer had this to say about coated pipes: “The risk of premature pipe failure as a result of damage during the installation of a culvert in a rockfill embankment is significant for coated steel pipes.

Damage to the coating will compromise its effectiveness; consequently, the estimated material service life for these culverts cannot accurately be determined. Therefore, only concrete culverts are acceptable at these locations because of the nature of the risk, the probability of occurrence, and most importantly, the consequences of premature failure.”

Over the past few decades, pipe products have tried to evolve with a continuously changing environment. It is for this reason that using an EMSL, as projected from short-term material tests, may not actually put the designer or specifier in a position of confidence as first thought.

A past article in the Concrete Pipe Journal, “Assessment of Gravity Pipe Systems – Initial Pipe Cost not the Primary Consideration” by Gerry Mulhern (Summer 2009 Issue), highlighted three critical assessments for pipe that should help close the loop on selecting the appropriate use of a pipe system: Technical (pipe design and pipe specification), Financial (EMSL, DSL, LCCA), and Risk (liability of failure).

While glossy brochures that project service life may seem well intended, nothing replaces the real application in the field. To assume that a “projected” EMSL will guarantee performance, and will remain unchanged, is a risk for project failure. If a DSL greater than 50 years is the intended design, then a designer has three options with current pipe materials:

1) Be patient for a few more decades in order to realize if steel or plastic pipe products can REPEATEDLY prove their purported field performance of 75 and 100 years;

2) Select pipe products that are unproven, AND accept the associated risk of limited field performance; or,

3) Use pipes that have a long history of proven performance in the field – CHOOSE concrete pipe.