The GeoEngineering Centre

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RESEARCH SUMMARY

INVESTIGATION OF THE FAILURE OF LARGE-DIAMETER CAST-IRON WATER MAINS USING A STOCHASTIC, PHYSICAL MODEL

INFLUENCE OF EARTH LOADS, VEHICLE LOADS, AND INTERNAL WATER PRESSURE CONSIDERED

EFFECT OF FROST AND TEMPERATURE GRADIENTS ALSO INCLUDED

CHANGES IN STRENGTH OVER TIME INCORPORATED CONSIDERING CORROSION CHARACTERISTICS OF THE PIPE AND THE SOIL

FACTORS OF SAFETY CALCULATED CONSIDERING DEMAND AND RESISTANCE

STOCHASTIC (MONTE CARLO) ANALYSIS WAS THEN USED TO ESTIMATE PROBABILITY OF FAILURE

HIGHLIGHTS

- **Considered 6 sources of tensile hoop stress**
- **Revealed the relative impact of different load sources, and provided guidance on site and pipe characterization needed to improve longevity estimates**
- **Large diameter mains in Hamilton and Kingston were ranked using factor of safety**

Many of the most critical water supply pipelines in cities across North America are large diameter cast iron pipes installed from 50 to 100 years ago. While public utilities have limited resources to replace these, failure can lead to substantial water damage and can increase the risks associated with fire and economic loss. Rational procedures were therefore developed to calculate the factor of safety against rupture considering the impact of different geometrical, structural, hydraulic, environmental factors.

The physical model estimates both the time-dependent factor of safety and probability of failure of large-diameter cast-iron water mains. Failure for these large diameter pipes is assumed to occur by longitudinal cracking caused by tensile hoop stress and a reduction in the strength of the pipe due to corrosion pitting. Six different load sources were considered associated with the earth load, live load, frost load, internal water pressure, and the curvature caused by the live load.

The model was then used in a two-part sensitivity analysis to determine the influence of each input of the model outputs. The first part of the analysis was deterministic and considered all 28 input variables. This identified six variables as having a high impact: the pipe wall thickness, the pitting depth scaling constant, the corrosion rate inhibition factor, the fracture toughness, the constant S in the residual tensile strength calculation, and the pipe diameter.

The second part of the sensitivity analysis involved stochastic calculations to investigate in more detail the key variables identified in the deterministic analysis. Mean factor of safety and probability of failure were determined to be very sensitive to pipe wall thickness, corrosion rate, and the constants used to calculate the residual tensile strength, but were relatively insensitive to pipe diameter.

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Wall of a large diameter cast iron water pipe showing extensive corrosion damage

ASSESSMENT OF PIPES IN HAMILTON AND KINGSTON

Daniel completed his work by undertaking assessments of 20 large diameter cast iron water mains in the City of Hamilton, and 4 in Kingston. These assessments provide input on the factors that control calculated factors of safety, and so the likelihood of failure over time. While the analysis still requires experimental evaluation, an assessment of different water pipe assets facilitates rankings to identify which pipes are most vulnerable, which are expected to have the longest remaining service lives, and what additional information could be collected to improve these assessments.