

# Long-Term Performance Prediction for PE Pipes [Project #2975]

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## **PRINCIPAL INVESTIGATORS:**

Paul Davis, Stewart Burn, Scott Gould, Mark Cardy, Grace Tjandraatmadja, and Paul Sadler

## **OBJECTIVES:**

The objectives of this study were to (1) review the current field performance for polyethylene (PE) water pipelines; (2) review U.S. and international standards for PE water pipes; (3) review previous and state-of-the-art test methods and modeling techniques for service lifetime prediction of PE pipelines; (4) identify and measure relevant pipe properties that govern long-term field performance; and (5) develop and benchmark models to predict long-term field performance of PE pipes.

## **BACKGROUND:**

International experience indicates that PE often exhibits the lowest failure rate of all materials in use. Many failures are due to third-party damage or poor joint preparation rather than failure under normal service loading conditions. While low failure rates should also be expected in the United States, there is insufficient historical data to extrapolate future failure rates. This project develops models to predict the long term performance prediction for PE pipes in the United States.

## **HIGHLIGHTS:**

1. Many reported failures in PE water pipes occur by external damage or inadequate fusion jointing. Failure rates of PE pipes under normal operating conditions are extremely low.
2. PE materials have undergone significant changes since their introduction. The performance of current PE water pipes cannot be forecasted based on experiences with previous PE generations.
3. Superior performance of current PE pipes is attributed to fibrillated zones (or craze zones) that form at the tip of defects or damage in the pipe wall.
4. A physical probabilistic model has been developed to predict PE pipe failure rates. Comparison with historical data from U.K. water utilities shows good agreement.

## **APPROACH:**

To isolate the craze zone in PE materials, circumferentially deep notched tensile specimens were subjected to different static loads. Data was fitted to an empirical model to predict failure times for the craze zone developed at the tip of a crack in PE pipe. To benchmark the model, a laboratory test rig was built to subject PE pipes to combined internal pressure and diametrical deflection loads. Measured failure times were compared against predictions from the theoretical craze failure model. The craze failure model was expanded to predict network-wide failure rates using a Weibull probability distribution for pipe defect size. A computer program for Monte Carlo simulations of the craze failure model was then written using the Python programming language. The U.K. Water Industry Research (UKWIR) national mains failure database was used to benchmark the model predictions.

## **RESULTS/FINDINGS:**

### **Field performance of PE water pipes**

In the United Kingdom and Australia, PE water pipes generally exhibit lower failure rates than other materials in use.

However, the failure descriptions used by U.K. and Australian water utilities can be misleading. Many fracture type failures are thought to be caused by external damage and inadequate jointing rather than failure under normal service loads. In the United States, anecdotal evidence from water utilities suggested that premature failures had previously occurred in PE service connections. However, it should be noted that the currently available grades of PE for water pipes have significantly improved resistance to cracking compared to those early grades used previously.

#### **Fracture resistance of PE water pipes**

Current PE materials have increased resistance to slow crack growth (SCG). This increased SCG growth is primarily due to the ability of a material to form large fibrillated zones at the tip of any defects or damage sites in the wall of a PE pipe. This zone (or craze) is able to extend and absorb energy, which reduces crack growth rates. Experimental assessment showed that currently available U.S. and Australian PE materials have significantly higher craze strengths compared to previous PE grades.

#### **Predicted failure rates in PE pipe networks**

Based on measured craze resistance, a model was developed to predict the decrease in craze strength over time. The model was extended to predict failure time for a craze zone at the tip of a defect in the pipe wall. Comparisons with experimental tests on pipe sections subjected to combined internal pressure and deflection loads were favorable. Comparisons with actual historical failure data from 17 U.K. water utilities showed good agreement. The relatively high craze resistance of current U.S. PE materials is reflected in a very low predicted future failure rate.

#### **IMPACT:**

The experimental findings from this project demonstrate that the fracture performance of currently available PE materials is significantly improved from previous material grades. This indicates that the future performance of these current PE materials should not be assessed based on previous historical data held by water utilities. The simple equations provided from the physical probabilistic failure model in this study provide water utilities with a basis for estimating future failure rates. This information can be combined with knowledge of cost consequences of pipe failure and used to inform future asset management decisions, such as replacement planning and budget setting.

#### **RESEARCH PARTNER:**

Commonwealth Scientific & Industrial Research Organization

#### **PARTICIPANTS:**

Twenty-nine U.S. water utilities provided data and anecdotal information on their experiences with the field performance of PE water pipes.