Failure of Prestressed Concrete Cylinder Pipe (PCCP) [Project #4034]

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PRINCIPAL INVESTIGATORS:
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OBJECTIVES:
The objectives of this project were to (1) develop a prestressed concrete cylinder pipe (PCCP) evaluation method, (2) determine the causes of PCCP failures, and (3) conduct a statistical analysis of PCCP failure data to provide service life prediction models.

BACKGROUND:
Reports of water pipelines failing can be sensational, particularly where the resulting flood damage provides spectacular footage for the 10 o’clock news. These failures, some of which are PCCP, also cost significant sums for repair and eventual pipeline replacement. PCCP tends to be of large diameter, making failures of this type of pipe relatively catastrophic and costly. To date, most research has been focused on PCCP inspection technologies and performance prediction in order to minimize the risk to utilities from such failures. This study is intended to provide more data useful for the prediction of PCCP service life.

HIGHLIGHTS:
This report presents data collected from this study, as well as expands upon previous studies on PCCP failures. The project began with a workshop with water utilities having a fair amount of PCCP in their systems, selected carefully to represent the range of conditions and variables that affect PCCP performance across North America. A database of 592 PCCP failures was developed and then statistically projected over the installed PCCP base of North America. The results provide a surprising indicator of failures and failure rate of PCCP. A timeline was developed to determine when PCCP was made, when it failed, and what events (such as changes to design and material standards) may have affected its performance. This timeline was also statistically analyzed against the failure data to provide performance prediction tools.

APPROACH:
A workshop was held to develop a procedure to allow a utility to self-assess its PCCP pipelines based upon its existing knowledge base, followed by application of that assessment method to confirm its usefulness. A timeline of PCCP manufacture was developed to chart changes in manufacturing and installation practices that may have affected PCCP performance. Modes of PCCP failure were determined and a database of 592 failures was established and then statistically analyzed to determine causes of failure. The data were grouped based upon the AWWA standard in effect in the year of manufacture. Ogive and Weibul probability distributions were calculated to determine probability of failure for seven PCCP manufacturing eras.

RESULTS/FINDINGS:
The initial design basis for manufacture of PCCP appeared to be conservative, and as experience was gained and competitiveness with other pipe materials increased, changes were made in the standard to reduce the unit cost of manufacture. Those changes tended to increase the stress level in the pipe at working pressures and reduced the margin for error. The result was a significantly increased rate of failure for pipe installed...
between 1971 and 1979. Fully 50 percent of the catastrophic leaks and breaks recorded were manufactured or installed between those years.

The trend toward reduced conservatism of the product through revisions in the standard began to reverse course in 1984 with the issuance of AWWA C301-84. That year saw the allowable additions of fly ash and other pozzolans in an attempt to increase the density of the concrete coating and core, the incorporation of ASTM C33 for concrete and mortar aggregate requirements, the slurry placement under the wire, and an increase in the minimum coating thickness to 3/4 inch. Significant revisions to the standard in 1992 and adoption of the very detailed design standard C304-92 appear to have resulted in much improved performance of installed PCCP.

**IMPACT:**
Matrices developed for both lined-cylinder construction type PCCP and embedded-cylinder type PCCP provide a tested tool to PCCP-owning utilities to assist them in identifying PCCP at risk of failure. The tool is intended to be used as a screening method to allow allocation of resources toward the PCCP at greatest risk of failure. Histograms are included that allow both determination of PCCP failure frequency by year of manufacture as well as comparison of the relative differences in failure frequency. Statistical analyses of the populations based upon the AWWA standard in effect in the year of manufacture, using Ogive and Weibull methods, allow preliminary estimates of remaining service life of PCCP pipelines.

**RESEARCH PARTNER:**
USEPA

**PARTICIPANTS:**
Twenty-two utilities in the United States participated in this project, representing approximately 6 percent of the total PCCP installed.