Evaluation of Asbestos Cement Pipe Condition

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Abstract

The project investigates the deterioration of the AC pipes in their operation environment and the correlation between deterioration and likely contributing factors. An asset management framework, which assists the Water Corporation's capital planning and helps target the available capital to areas of replacement, has been developed based on the outcomes of the investigation. The objectives are accomplished in two aspects: (1) archive data analysis to establish correlation between environmental conditions and failure rates of AC pipes, and (2) laboratory experimentation to establish an understanding of the deterioration mechanisms of the AC pipes. Finally, it is found that the pipe service life, which was originally estimated to be around 80 years, is discovered to be closer to 50 years. According to the framework outcomes, more than half of the towns in WA will need to undertake major AC pipe replacement program within the next 10 years.

1. Introduction

The Water Corporation has about 11,000 km of underground Asbestos Cement (AC) pipes, which makes up 33% of the total water pipe (Jarvis 1997). The pipes have experienced increasing deterioration over the past few decades as a result of interactions with the operating environment with total replacement value estimated to be around $1 billion. The distribution and reticulation mains in WA operated by the Water Corporation consist of pipes of various materials, including cast iron, reinforced concrete, Plastic and asbestos-cement. The overall average failure rate for all pipe materials needs to stay within the requirement of the state wide regulatory target in order to fulfill the Water Corporation's commitment to providing reliable water services to the State's residents. A recent review has revealed an upward trend in the overall level of failures approaching the maximum acceptable and the class of AC pipes is identified as one of the key contributors to this trend as its burst rate is well over the target. Consequently, an effective tool for monitoring and keeping the failure rate of AC pipes under the regulatory target as well as assisting Asset Managers to make more informed replacement decisions, is needed.

The structural integrity of pipe reduces over time due to material deterioration, the mechanisms of which are dependent on the pipe material (Rajani & Zhan, 1996). A number of Water Corporation studies have been conducted in search for correlations between pipe failure and a range of likely deterioration-causing factors, in particular the Water Corporation Asbestos Cement Pipe Corrosion Interim Report prepared by Ben Jarvis. The report details a pipe condition evaluation model, which took into consideration the age of the pipe, water quality and surrounding soil environment and was constructed based on test results of pipe samples collected from around the State. Around the world, many utilities currently base replacement decisions predominantly on historic burst rate and do not exercise active prediction of remaining asset life for forward planning. The proposed framework is the first of its kind as it:

- integrates historic burst rates with all operating conditions that affect deterioration rate into a practical decision-supporting tool,

- ensures active prediction of future pipe performance, especially in towns when there is insufficient records of leak and burst history.

2. Methodology

Through the method of archived data analysis and experimental approaches, the correlation between AC pipe failure rate and the likely contributing factors were investigated.

Prior to undertaking the data analysis, literature review was carried out and it was suggested that failures can be categorised into two types: normal burst due to deterioration and accidental burst due to excessive loading. The deterioration are believed to result from chemical leaching of the cement material mainly due to aggressive reticulation water and surrounding soil environment, while the accidental damage can be result from tree roots, traffic loading and excavation activities.

The statistical analysis set out to investigate the major deterioration-causing factors that impact the normal failure rates of pipes.AC reticulation pipe failure work order data provided by the Water Corporation was used in this analysis. The data set covers a 14-year observation period from 1997 to 2011 and contains a total of 69,943 asset records accounting for a total of 10,730 km of AC pipe in length.

A Phenolphthalein test was carried out on 10 healthy pipe sections extracted from the flood plains near Port Hedland and Broome to confirm the extent of external leaching by aggressive soil environments.

3. Results and Discussion

3.1 Age Effects Analysis

An increasing level of failure, measured as normalised burst rate (NBR), was observed with an increase in pipe age.Figure1 below illustrates the state wide NBR for each pipe installation year. As can be seen from the figure, the age of pipes has a substantial impact on the failure rate, therefore it was taken into account as the first consideration in the framework.

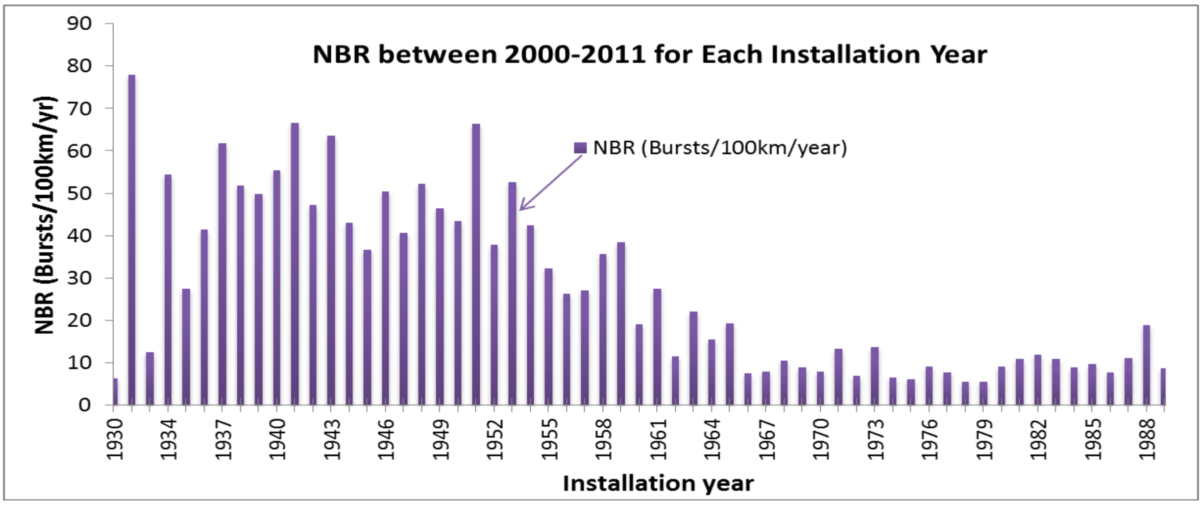

Figure 1 Normalised burst rate (NBR) against installation year for AC pipes

3.2 Environmental Effects Analysis

3.2.1 Soil Conditions

In WA, soil aggressiveness with respect to AC pipes is measured in terms of Cement Soil Aggressiveness Rating (CSAR) developed by Water Corporation. The rating takes into consideration four parameters, namely soil pH at 50-80 cm, water logging, soil salinity and corrosivity. Each pipe asset record in the database is assigned with a CSAR, which enables the correlation between CSAR and burst rate to be investigated. The outcome indicated a distinct correlation between pipe failure and CSAR. The results from the phenolphthalein test showing extensive external leaching on most AC samples, as shown in Figure 2, aligned with this finding. The soil condition of the pipe was therefore considered in the framework as one of the deciding factors of pipe performance.

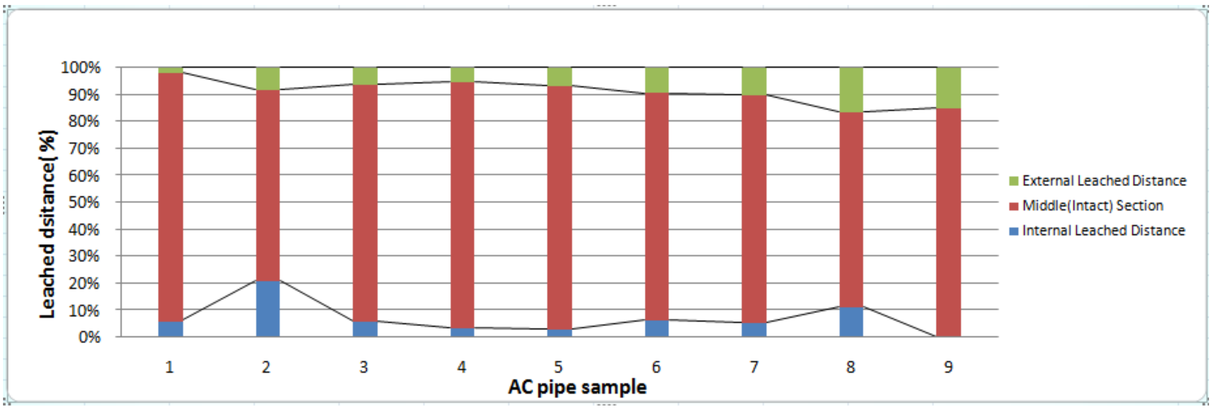

Figure 2 Phenolphthalein test outcomes: External and internal leached distance (as % of total pipe thickness) for samples

3.2.2 Reticulation Water Quality

The quality of reticulation water is connected to the water Aggressiveness Index (AI). The correlation between AI and pipe bursts was obtained by averaging the NBR from all decades against each AI range: less than 10 (extremely aggressive water), between 10 to 12 (moderately aggressive water) and greater than 12 (non-aggressive water). The results are summarized in Figure 3, with a notable correlation between aggressive water and high failure rate of pipe illustrated.

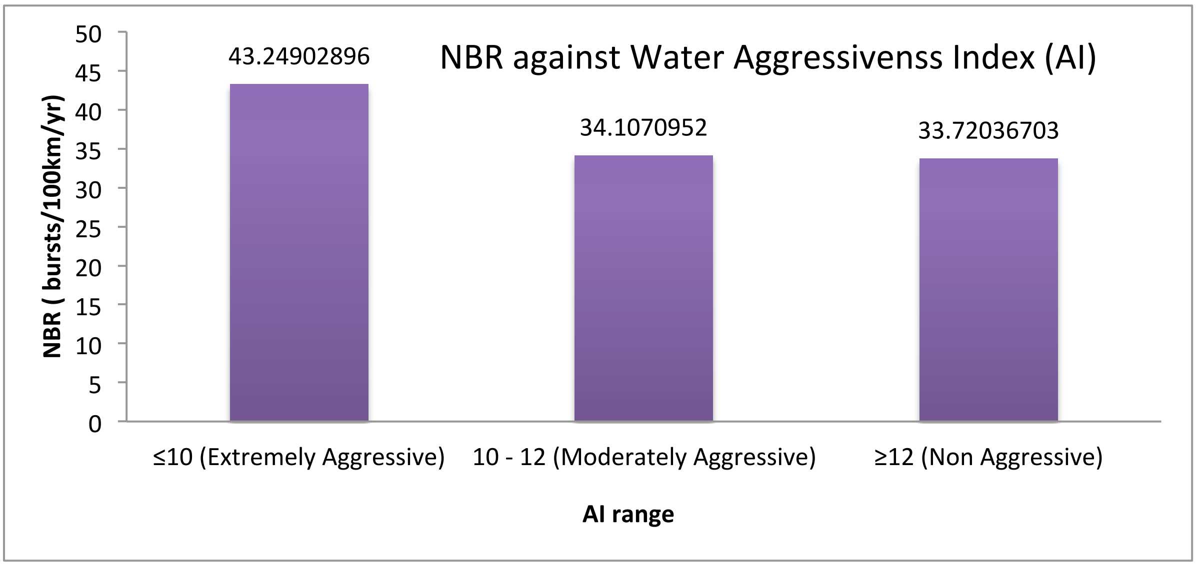

Figure3 Normalised burst rate (NBR) for different AI range

It was noted that in case of extremely aggressive water, the failure rate on average is approximately 28% higher than non-aggressive water, while moderately aggressive water is about 1% higher. As aggressive water results in a large difference in pipe performance, water quality also needs to be considered in developing the framework.

No significant correlation was found between burst rate and other parameters, such as pipe material, coating and water flow rate. We anticipated that no allowance for pipe type need be made in the modelling process (Jarvis, 1997). The effect of this bitumen coating on pipe corrosion is not expected to be very significant, however, based on previous pipe sampling (Jarvis, 1997).

4. Development of Framework

To develop the framework, the major factors identified were used as the basis of the framework. The items considered in the scheme are illustrated in Figure 4.

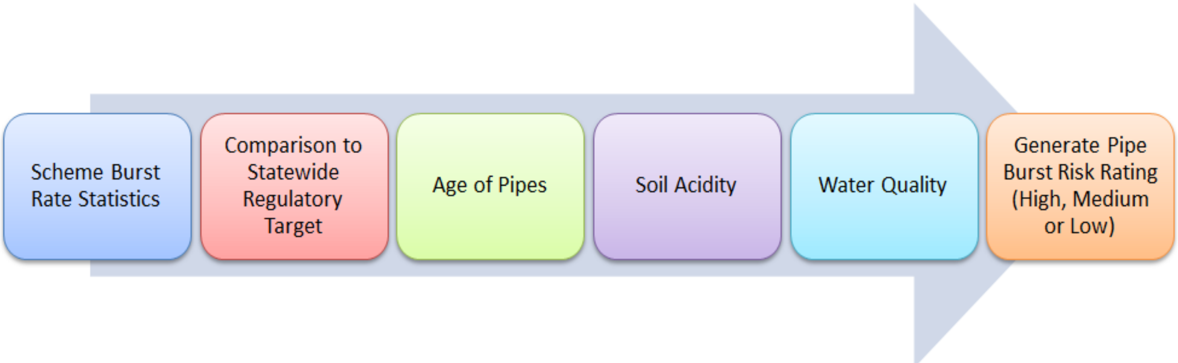

Figure4 Summary of assessment items and order in the framework

The proposed framework, as shown in Figure 5, is developed using local Normalised Burst Rate (NBR) as the first trigger as it most directly reflects the current pipe condition status. Local burst rate databases were built for each major town in Western Australia to provide region-specific NBR data for the model. If the pipes in a town exceed the maximum burst rate, a sampling program should be carried out to highlight the areas which require replacement. Otherwise, the predicted time for pipes to reach the maximum burst rate is calculated based on current burst rate and a risk rating is then assigned to it. Pipe age, having been shown to have the second strongest correlation with pipe deterioration, is assessed next. The age of pipes is compared to this region-specific service life allows a decision to be made between sampling or further assessment. From data analysis, the impact of aggressive soil and water conditions on pipe burst rate has been identified. Since the age of pipes differ within the same town, the pipes are split into groups of same installation decade and assessed separately. Burst likelihood rating to each pipe age group is determined. Each burst likelihood rating has a corresponding recommended reassessment frequency assigned to it. The frequency is optimised between possibly higher pipe burst due to infrequent assessment and expenditure for periodic assessments.

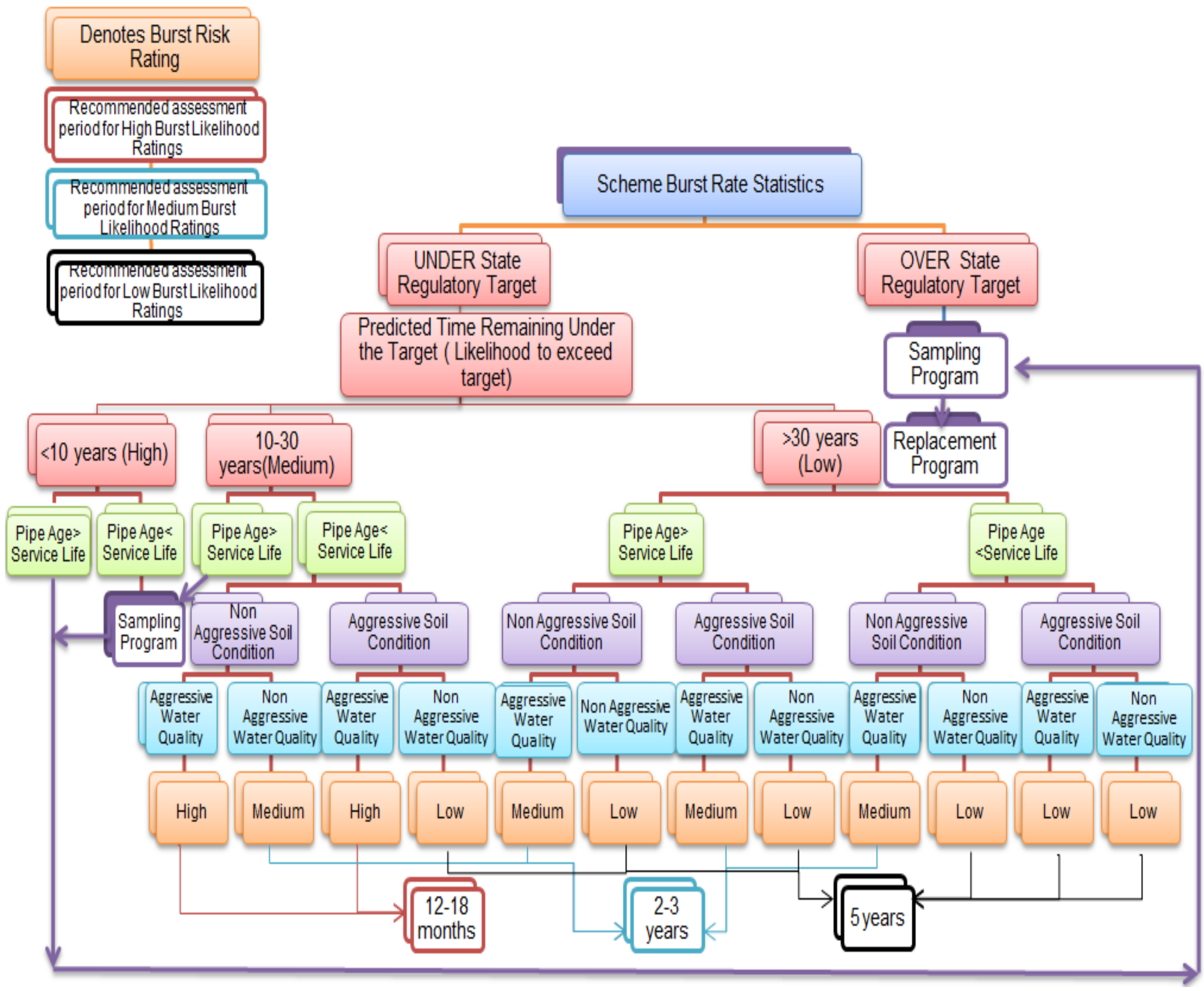

Figure5 A Schematic Representation of the Risk-Based Framework

5. Conclusions and Future Work

The proposed framework has been developed to provide capacity to develop a more robust strategy to both manage long term performance for AC pipes and also provided a clearer picture of future renewals funding needs. The framework generates recommended action plans on asset maintenance and renewals based on the current observed burst rate and predicted remaining life of AC pipes taking account of key operating conditions. The framework provides an effective tool for making more informed decisions by providing insights for those assets that may be younger, have no future history but where operating conditions may lead to short lives.

The framework can be further modified to deliver pipe condition predictions by regions instead of towns in order to accommodate pipes that lie outside the boundaries of any towns. Chemical immersion experiment, mechanical testing and microscopic analysis are currently being conducted and are expected to finish by the end of September. The results from the experiments and tests will help to quantify the impact of the above mentioned deterioration-causing parameters as well as to further enhance the accuracy of the framework outcomes.

6. References

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