ON ASBESTOS-CEMENT PIPELINE LONG-TERM ASSET PLANNING: FINANCIAL VIABILITY OF IN-LINE INSPECTIONS

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1. INTRODUCTION

Asbestos cement has been widely used as an affordable material for pipeline production. For example, 23% (28,000 km) of the Dutch drinking water distribution network consists of AC pipes [1]. Many of these networks are now approaching their expected end-of-life. In practice, a number of AC pipes appear to have expected lifetimes exceeding 100 years [2]. The question is then: *"how long will a given AC-pipe last and is it financially viable to perform an in-line inspection to verify the technical lifetime?"*

2. METHODOLOGY

In order to ascertain the viability of inspections, a few factors must be accounted for. Specifically, these are: the degradation rate of the AC, the predictability of this degradation rate and the costs associated with inspection and replacement.

There are many failure mechanisms applicable in AC pipelines, such as, but not limited to: leaching, sulphate attack, angular displacement, water hammer, activities of 3rd parties, etc. In this paper, only leaching was considered. It is known that all cement-based materials are prone to degradation through leaching [3].

Measured degradation cannot be extrapolated to other pipelines. For similar age AC pipes (± 11 years, pipe age between 35 and 46 years), degradation varied between 1% to 31% of the pipe wall cross-section [2].

Whilst almost all verifiable circumstances were approximately identical, great variability in the results indicate that even with most factors known, predicting AC degradation accurately appears unlikely, though it is not exactly known why [4]. A new dataset of 51 kilometres of pipeline was studied extensively and will be covered in chapter 3.1.

3. RESULTS AND DISCUSSION

In this chapter, the results of the aforementioned study will be discussed. Secondly, these results will be used in conjunction with a TCO (Total Cost of Ownership) model to ascertain the financial viability.

3.1 Residual life estimates

In order to evaluate whether a pipeline should be replaced, a residual life estimate (RLE) needs to be determined. The established threshold at 32% degradation of the pipe wall, according to [2], will be followed.
In table 1, below, a summary of the average RLE and the standard deviation of the dataset per pipeline is shown. As expected, the standard deviation (SD) varies greatly per pipeline, indicating that remaining life is inhomogeneous between different pipelines. Some pipelines have a very small SD, indicating homogeneous remaining length over its own length, where those with high SD indicate inhomogeneous ageing. This is consistent with [2].

Table 1: Distribution of residual life per pipeline

ID	Age [yr.]	Number of Pipe Segments	Average RLE (32% deg.) [yr.]	StdDevp [yr.]
1	41	1149	1	4
2	41	1077	48	23
3	37	356	14	11
4	41	1288	2	6
5	49	293	57	17
6	37	278	-11	6
7	36	1273	26	14
8	43	105	-20	2
9	40	287	-8	4
10	39	296	235	99

11	46	538	153	53
12	51	1647	1	11
13	45	219	0	6
14	52	498	-17	5
15	50	371	24	16
16	48	499	-10	4

3.2 Financial Viability

Performing an ILI is often experienced as an expensive undertaking. Whether inspecting a near theoretical-end-of-life pipeline is financially viable depends on whether the inspection results allow the pipeline to be serviced for enough years to cover the inspection costs.

In order to estimate the amount of money saved by extending the lifetime of the pipeline, a TCO model was used. In this model, all expenses related to the pipeline are summed up and converted into a yearly cost of ownership. The replacement cost of a fictional, 10km pipeline was assumed to be a fixed value of €15M (€1500 per meter). This is a ballpark figure, based on [5]. The expected lifetime of the pipeline was set to 50 years. The cost of an ILI was estimated at €150,000.

The pipeline is subject to the 'bathtub curve' of failure rates [6]. The TCO was modelled as follows, where TL is the technical lifetime and EL is the economic lifetime of the pipeline:

$$OPEX(age) = \begin{cases} €600.000 - (€100.000 * age) & if\ 0 < age < 5 \\ €100.000 & if\ 5 < age \leq TL \\ €100.000 + \left(€50.000(age - TL)\right) & if\ age > TL \end{cases} \quad (1)$$

$$TCO(EL) = IC + \sum_{age=0}^{EL} OPEX(age) \quad (2)$$

$$ACO(EL) = \frac{TCO(EL)}{EL} \quad (3)$$

Equation 1 models the yearly operational expenditure (OPEX) dependent on pipeline age. Equation 2 finds the TCO, consisting of installation costs (IC) and OPEX. By dividing the TCO by EL, an annual cost of ownership (ACO) is determined. Below, in table 2, cost-saving estimates were produced for lifetime extension increments of 10 years, as well as the current optimum at a lifetime extension of 18.6 years; the average remaining life beyond 50 years of the dataset shown in table 1. If an ILI was performed on the model pipeline, it would be financially viable if the lifetime extension is upwards of two (2) years.

Table 2: Distribution of residual life per pipeline

Years Extended (Technical Lifetime)	Yearly TCO Savings after ILI
10 (60)	€ 40,796.70
18 (68)	€ 69,781.75
20 (70)	€ 75,048.26
30 (80)	€ 101,269.36
40 (90)	€ 122,062.21
50 (100)	€ 137,142.86

3.3 Limitations

There are a number of points on which further research or an improvement in data quality could enhance this report. Firstly, the accredited costs used in the TCO model require validation. Secondly, the matter of residual life estimation of AC piping is still a debated topic in the field, as no governing body has produced a definite methodology. It is entirely based upon practical experience and small scale research projects conducted over the past few decades.

4. CONCLUSION

It is required that a given AC pipe be subjected to an ILI in order to accurately determine its current state of degradation. This inspection will in almost all cases lead to either a lifetime extension (when at theoretical end-of-life) or prove the pipeline to be in need of immediate action. Since a lifetime extension of only 2 years would already be cost-effective, the odds are ever in their favour.

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