1. Predicting the Service Life of Concrete Sewer Pipe.

1.1 Introduction

To determine the service life of a concrete sewer pipe at a given location it is necessary to calculate the loss of material over time and compare the predicted cumulative loss of concrete since installation with the original depth of concrete covering the sewer pipe reinforcement (the "concrete cover"). It is assumed that once the metal reinforcement of the pipe is exposed, failure of the pipe is imminent and consequently the effective service life of the pipe is at an end.

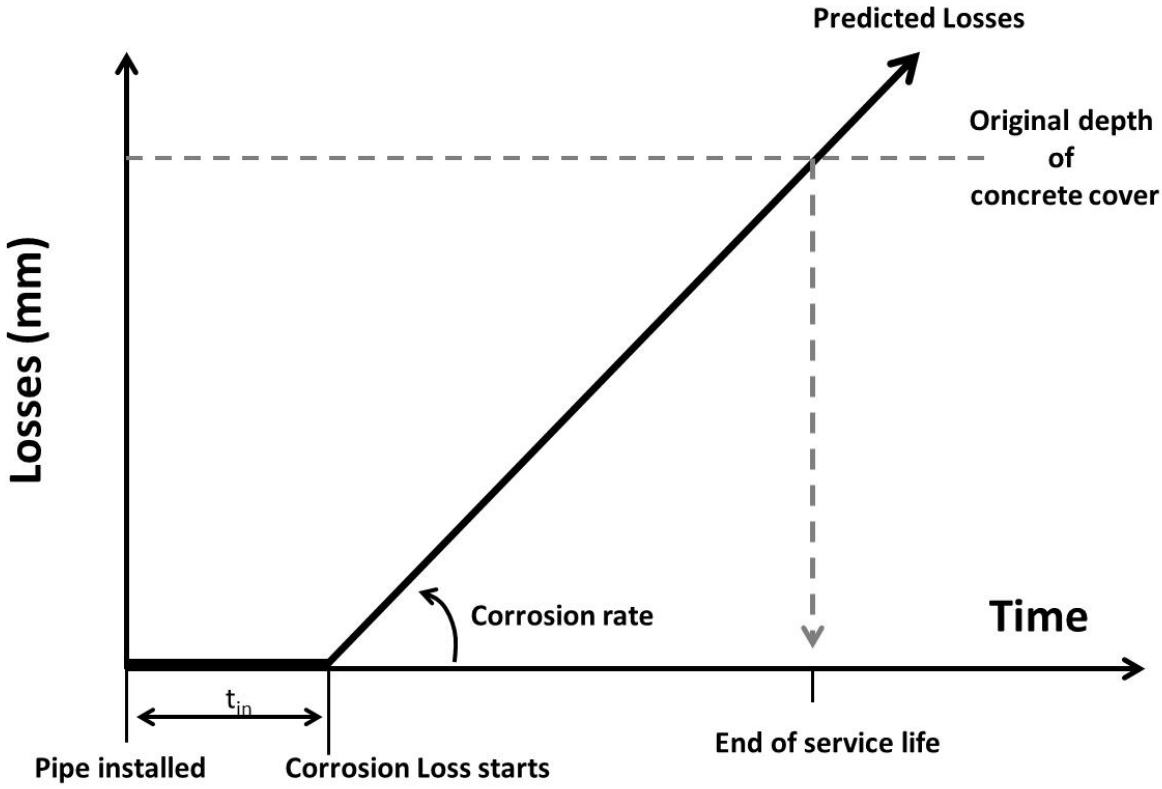

Figure 1. The method by which service life is determined.

Corrosion of concrete sewer pipe is a 2 step process (refer to Figure 1):

1. For a short period of time after installation (the "incubation time" or t_{in}) there is no significant loss of concrete cover as the pipe is too alkaline to support the activity of acid producing bacteria that are responsible for corrosion of the pipe.

2. After the incubation period has ended loss of concrete begins and if local sewer environmental conditions remain unchanged, losses will accumulate at a constant rate

for the remainder of the service life of the pipe, (i.e. once the mass loss starts the rate of corrosion is constant).

The cumulative corrosion loss is calculated using the following expressions:

$$\begin{aligned} &\textit{Cumulative Losses (mm)} = 0 && t<t_{in}; \\ &\textit{Cumulative Losses (mm)} = CR\times(t-t_{in}) && t>t_{in} \end{aligned} \quad (1)$$

Where CR is the rate of corrosion, (mm/yr), calculated and t_{in} is the incubation time (years). Both CR and t_{in} are calculated from the local sewer environmental conditions.

The service life of the sewer pipe is:

$$\textit{Service life (years)} = \frac{CD_{t=0}}{CR} + t_{in} \quad (2)$$

Where $CD_{t=0}$ is the depth of concrete cover over the metal reinforcement at time=0 (mm); *CR* is the rate of corrosion, (mm/yr), and t_{in} is the incubation time (years).

1.2 Calculation of concrete sewer pipe service life

In order to calculate the pipe service life it is necessary to determine the characteristic corrosion rate , *CR*, for the site and the incubation period, t_{in}. Both functions can be estimated from the temperature, humidity and H_2S concentration of the sewer atmosphere (or headspace) as follows:

$$t_{in}(years) = 1.24\times10^{-10}\times[H_2S]^{-0.8}\times\frac{(0.0955\times RH\% - 9.8044)}{(1-0.01245\times RH\%)}\times e^{(56{,}000/(8.314\times(T+273)))} + 0.91 \quad (3)$$

$$CR\ (mm/yr) = 458000\times[H_2S]^{0.5}\times\frac{(1-0.01245\times RH\%)}{(0.0955\times RH\% - 9.8044)}\times e^{(-30{,}000/(8.314\times(T+273)))} \quad (4)$$

Where $[H_2S]$ is the concentration of H_2S in the sewer gas (ppm); *RH%* is the sewer gas relative humidity (%) and *T* is the sewer gas temperature (°C). All values are the best estimates for the average values expected at the sewer site in question.

If only the H_2S concentration is known t_{in} can be estimated using the following expression:

$$t_{in}\ (years) = 1.62 - 0.083\times\ln[H_2S] \quad (5)$$

And *CR* from the following:

$$CR\ (mm/yr) = 0.56\times[H_2S]^{0.5} \quad (6)$$

This last expression assumes that the average temperature in the sewer will be 22°C and the average humidity 95% which an analysis of historical industry historical indicates as good averages for calculating rates of corrosion.

Important Note:

It should be stressed however that equation (6) should be used as a first estimate of CR only and that the predicted corrosion rate may significantly understate the actual corrosion rate especially if the actual sewer humidity is approaching 100%. If this is the case the actual pipe service life will be significantly less than that predicted .

The level of uncertainty in the value of *CR* calculated is estimated to be 1.5mm/yr.

To calculate sewer pipe service life:

1. Estimate sewer gas temperature, humidity and H_2S concentration
2. Calculate t_{in} and CR using equations (3) and (4) if all three environmental variables are known or equations (5) and (6) if only H_2S levels are known
3. For a given level of concrete cover depth it is then possible to calculate the service life using equation (2).

Further information can be obtained as follows:

ARC Corrosion Linkage Project Final Report on Identification of controlling factors for the corrosion rate of concrete (SP1B).

A excel program ("service life estimation.xls") which carries out the service life calculations using the above equations is also available within the knowledge management system.
