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Residual life Estimate of Cast Iron Pipes through analysis of corrosion rates

Hyundong Lee[1,2], Hongcheol Shin[2]

[1] Korea Institute of Civil Engineering and Building Technology, Environmental and Plant Engineering Research Institute. 283 Goyangdae-ro, Ilsanseo-gu, Goyang-si, Gyeonggi-do, Republic of Korea
[2] University of Science and Technology, Construction and Environment Engineering. 217, Gajeong-ro, Yuseong-gu, Daejeon, Republic of Korea
{hdlee, hcshin}@kict.re.kr

Abstract. Water leakages in water distribution systems cause enormous economic damage and destabilize such systems. To estimate residual life in this study, a total of 34 cast-iron pipes (CIPs) including ductile cast-iron pipes (DCIPs) from differing laying environments in P city were used. After assessment, we therefore determined that an improvement plan based on a residual life assessment was more efficient than a traditional plan based on laying year.

Keywords: Residual life, Water distribution systems, Leakage

1 Introduction

The 2013 Water Supply Statistics, published by the Ministry of Environment in 2014, show that, of the total annual domestic water supply of 6,159 million m^3, a leakage of 656 million m^3 (10.7%) occurred. Water leakages in water distribution systems cause enormous economic damage and destabilize such systems. Corrosion and aging are the main reasons for leakages from pipes laid under the ground. The outside of underground water supply pipes comes into contact with soil, while the inside is in contact with treated water.

Through an evaluation of the internal and external residual thicknesses, a residual life assessment can minimize leakages caused by internal and external corrosion.

2 Materials & Method

2.1 Pipeline collection

To estimate the residual life of CIPs in domestic and metropolitan contexts, 34 CIP and DCIP samples from different laying environments were collected in P city. The

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regional statuses of the collected pipes are shown in Table 1. As shown in Table 1, most of the pipes (n = 21) were laid from 1976 to 1985, the diameters of most of the pipes are in the 100 mm–200 mm range, and most were buried in residential or commercial areas.

Table 1. No. of Pipe samples collected(part)

NO.	Samples	Pipe type	Laying year	Pipe diameter (mm)	Maximum water pressure (kgf/cm^2)	Laying areas
1	P-A-02	CIP	1968	200	-	Road
2	P-B-01	CIP	-	200	5(3.5)	Coastal
3	P-B-02	CIP	1980	150	5(3)	Coastal

2.2 Factors of assessment for corrosion rate

Corrosion depth

To measure the residual thicknesses of the CIPs and DCIPs in this study, a Shot-Blasting process was used to remove internal and external corrosion products and GPCs. After that, the initial pipe-wall thickness, internal maximum corrosion depth, and external maximum corrosion depth were estimated using a dial depth gage and a dial caliper gage.

Residual thickness

$|R_t| = I_t - (E_{mcd} + I_{mcd})$ Eq. (1) if $|R_t| \leq 0, R_t = 0$, or $|R_t| > 0, R_t = R_t$

Where, R_t = Residual wall thickness of pipe, mm
I_t = Initial pipe wall thickness of pipe, mm
E_{mcd} = External maximum corrosion depth of pipe, mm
I_{mcd} = Internal maximum corrosion depth of pipe, mm

Corrosion rate

$$E_{mcr} = \frac{E_{mcd}}{y} \quad \text{Eq. (2)} \qquad I_{mcr} = \frac{I_{mcd}}{y} \quad \text{Eq. (3)}$$

Where, E_{mcr} = External maximum corrosion rate of pipe, mmpy
I_{mcr} = Internal maximum corrosion rate of pipe, mmpy
y = Periods of laying, year

$$I_{mcr} = \frac{I_{mcd}}{y - t_n} \quad \text{Eq. (4)}$$

Where,

t_n = Periods required of CML being 100% neutralization = $\frac{100\% - CML\ neutralization}{Rate\ of\ CML\ neutralization}$

Rate of CML neutralization = $\frac{CML\ neutralization\ ratio}{Periods\ of\ \pi pe\ laying}$

Residual life

$$R_{lf} = \frac{R_t}{[E_{mcr} + I_{mcr}]} = \frac{R_t}{C_t} \quad \text{Eq. (5)}$$

Where, R_{lf} = Residual life of pipe, year
C_t = Maximum corrosion rate, mmpy
R_t = Residual thickness of pipe, mm

3 Results and Conclusion

Table 2. Prediction of residual life on CIP of P city(average)

Samples	Pipe type	Laying year	Periods of laying (year)	Residual life of pipe (year)			Total life of pipe (year)
				R_{lf1}	R_{lf2}	R_{lf}	
	Average		21.16	11.28	10.52	12.40	33.52

Table 3. Prediction of residual life on DCIP of P city(average)

Samples	Pipe type	Laying year	Periods of laying (year)	t_n (year)	Residual life of pipe, R_{lf1} (year)	Total life of pipe (year)
	Average		12.83	30.00	38.50	51.33

An improvement plan should therefore be established to improve the leakage-prevention capacity of water supply pipes before the end of the residual lives. Also, for P-H-3, the residual life was very short even though it was buried recently, and for P-A-02, 32 years had passed since the laying year, but its residual life was estimated at 29 years. It is therefore more economic and efficient to prevent leakage by properly estimating the residual life of a water supply pipe instead of using the existing improvement plan, whereby only the laying year and the age of the pipe are considered.

In Table 2, the total life year is the sum of the duration since the laying year and the residual life. For CIPs in P city, the estimated average total life is 33.52 years, indicating that only one-third of the total life years remain for the CIPs in P city.

For the DCIPs shown in Table 3, the average residual life is 38.50 years, which is 3 times higher than that of the CIPs, and the total life year estimate is 51.33 years; therefore, one-half of the total life years remain for the DCIPs in P city. The total life of the DCIPs in P city is approximately 1.5 times longer than that of the CIPs in P city; however, the improvement of the DCIPs should be completed before the neutralization of the CML due to the rapid procession of internal corrosion after neutralization.

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