Nomenclature alphabetical order

$2a$ Patch length (mm)

$2a'$ Critical patch length (mm)

$2b$ Patch width (mm)

$2b'$ Critical patch width (mm)

A Area of flow (mm^2)

c Patch depth (mm)

c' Critical patch depth (mm)

c_{ACe} External deterioration rate for AC pipes (mm/y)

c_{ACi} Internal deterioration rate for AC pipes (mm/y)

c_d Discharge coefficient

c_l Coefficient for strength reduction

c_{lc} Coefficient for creep modulus reduction

c_{lf} Coefficient for fatigue strength reduction

c_s Intercept parameter for long-term corrosion of metallic pipes (mm)

C Compression modulus (GPa)

C_f Fatigue constant for host pipe under cyclic surge pressure

C_{HW} Hazen Williams roughness coefficient

C_n Total cash flow for each year ($)

$C_n(t)$ Nominal cash flow ($) at time t

C_{nothing} Cost of do nothing option ($)

$C_r(t)$ Real cash flow ($) at time t

CRF Creep retention factor of the liner

$CRF(t)$ Creep retention factor at design lifetime t

$CRF(\beta t)$ Creep retention factor at time βt

d Initial hole (defect) size (mm)

d_f Future hole (defect) size (mm)

D Pipe internal diameter (mm)

D_0 Pipe external diameter (mm)

D_L Liner external diameter (mm)

D_{Li} Liner internal diameter (mm)

D_M Mean diameter of the host pipe (mm)

DN Pipe nominal diameter (mm)

E_a Young's modulus of the adhesive (GPa)

E_A Short-term tensile or compressive modulus of the liner in the axial direction (GPa)

E_{fa} Short-term flexural modulus of elasticity (axial) of the liner (GPa)

E_{fal} Flexural creep modulus (axial) of the liner (GPa)

E_{fh} Short-term flexural modulus of elasticity (hoop) of the liner (GPa)

E_{fhl} Flexural creep modulus (hoop) of the liner (GPa)

E_L Short-term modulus of elasticity of the liner (GPa) and is the greater value of: the short-term modulus of elasticity in the liner in the hoop (E_{th}) or axial direction (E_{ta})

E_{LB} Short-term modulus of elasticity of the liner (GPa) for buckling and is the lesser value of: the short-term modulus of elasticity in the liner in the hoop (E_{th}) or axial direction (E_{ta}).

$E_{l,dry}$ Dry creep modulus of the liner (GPa)

$E_{l,wet}$ Wet creep modulus of the liner (GPa)

E_p Modulus of elasticity of host pipe material (GPa)

E_s Soil modulus (MPa)

E_t Short-term tensile modulus of elasticity of the liner (GPa)

E_{ta} Short-term tensile modulus of elasticity (axial) of the liner (GPa)

E_{tal} Tensile creep modulus (axial) of the liner (GPa)

E_{th} Short-term tensile modulus of elasticity (hoop) of the liner (GPa)

E_{thl} Tensile creep modulus (hoop) of the liner (GPa)

E_{tl} Tensile creep modulus of the liner (GPa)

f Friction coefficient of the interface of the host pipe and liner

g Acceleration due to gravity (m/s^2)

h Pressure head (m)

H Burial depth (mm)

H_w Groundwater depth (mm)

i Discount rate (%)

IN Inflation rate (%)

I_o Initial investment ($)

k Lateral earth pressure coefficient

k_1 Patch factor

k_2 Aspect ratio

K Enhancement factor

K_{IC} Fracture toughness of host pipe material (MPa m$^{1/2}$)

L Installation length of the liner (m)

L_{cost} Cost of the liner ($/m)

L_{mis} Miscellaneous liner cost ($)

L_c Critical crack length (mm)

L_p Length of the pipe (m)

L_{ps} Length of the pipe spool (m)

m_f Fatigue constant for host pipe under cyclic surge pressure

$MAOP$ Maximum allowable operational pressure (MPa)

n_f	Cyclic surge factor
n_{PC}	Number of recurring cyclic surge pressure cycles per day
n_{TPC}	Total number of surge pressure cycles for the service life of pipe/lined pipe
N	Safety factor for host pipe
N_i	Factor of safety for liner imperfections
NPV	Net present value ($)
P	Operating pressure (MPa)
P_G	Groundwater load (MPa)
P_{GC}	Groundwater load capacity (MPa)
PN	Nominal pressure (bar)
P_N	External pressure on the liner (MPa)
P_T	Test pressure (MPa)
P_c	Recurring cyclic surge pressure (MPa)
P_{max}	Maximum allowable pressure (MPa)
P_{min}	Minimum internal pressure (MPa)
P_s	Surge pressure (MPa)
P_v	Vacuum pressure (MPa)
q_t	Total external pressure on pipes (MPa)
q_{tc}	Liner capacity for total external pressure (MPa)
Q	Leak rate (L/s)
r_s	Minimum corrosion rate (long-term) of metallic pipes (mm/y)
r_{sh}	Lateral extension rate for metallic pipes (mm/y)
r_{sv}	Radial corrosion rate for metallic pipes (mm/y)
R_{cost}	Cost of replace option ($/m)

R_h	Hydraulic radius (m)
R_{mis}	Miscellaneous replace cost ($)
R_W	Water buoyancy factor (unitless)
S	Slope of the energy grade line, or head loss per unit length of pipe (m/m)
SCF	Stress concentration factor
SCF'	Critical stress concentration factor
t	Time (years)
t_h	Time (hours)
T	Pipe wall thickness allowing for uniform corrosion (mm)
T_{ext}	Estimated external uniform corrosion (mm)
T_f	AC pipe remaining wall thickness at failure (mm)
T_{int}	Estimated internal uniform corrosion (mm)
T_L	Liner thickness (mm)
T_n	Pipe nominal wall thickness (mm)
u_g	Existing gap width of host pipe (mm)
u_{gp}	Gap formed due to axial movement or pulling force (mm)
V	Flow velocity (m/s)
W	Traffic load (kN)
W_s	Live load (MPa)
x_l	Coefficient for strength reduction
x_{lc}	Coefficient for creep modulus reduction
x_{lf}	Coefficient for fatigue strength reduction
y_f	Predicted year for failure of an AC pipe (mm)
α	Coefficient of thermal expansion (mm/mm/°C)

β	Fraction of liner service life when out of service
γ_s	Soil unit weight (kN/m^3)
γ_w	Unit weight of water (kN/m^3)
Δ	Host pipe ovality (%)
ΔT	Temperature change (°C)
θ	Rotation angle (°)
ν_L	Poisson's ratio of the liner
ν_p	Poisson's ratio of host pipe material
σ_A	Short-term tensile or compressive strength of the liner in the axial direction (GPa)
σ_{ad}	Adhesion strength of the liner to host pipe substrate (MPa)
σ_{fa}	Short-term flexural strength (axial) of the liner (MPa)
σ_{fal}	Long-term flexural strength (axial) of the liner (MPa)
σ_{fh}	Short-term flexural strength (hoop) of the liner (MPa)
σ_{fhl}	Long-term flexural strength (hoop) of the liner (MPa)
σ_{max}	Maximum stress in the liner (MPa)
σ_p	Tensile stress in the host pipe (for AC pipe) (MPa)
$\sigma_{t,AC}$	Ultimate tensile strength of AC (MPa)
σ_t	Tensile strength of the liner (MPa)
σ_t	Ultimate tensile strength of host pipe material (MPa)
σ_{ta}	Short-term tensile strength (axial) of the liner (MPa)
$\sigma_{tal,r}$	Tensile rupture strength (axial) of the liner (MPa)
σ_{th}	Short-term tensile strength (hoop) of the liner (MPa)
$\sigma_{thl,r}$	Tensile rupture strength (hoop) of the liner (MPa)

σ_{thl} Long-term strength (hoop) of the liner and is the lesser value of either: the tensile rupture strength (hoop), $\sigma_{thl,r}$ (MPa) or fatigue strength (hoop), $\sigma_{thl.f}$ (MPa)

$\sigma_{thl.f}$ Fatigue strength (hoop) of the liner (MPa)

σ_y Yield strength of steel (MPa)

τ Transition period between short-term and long-term corrosion (y)

Φ Soil friction angle (°)

ϕ_c Wet creep reduction factor

ϕ_s Wet strength reduction factor