Rehabilitation of Fully Deteriorated Rigid Pipes

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Rehabilitation of Rigid Pipes

Background
ANSI/AWWA C950-88

McAlpine Papers-1993 (No-Dig & ASCE/PLD)

Schrock & Gumbel Paper-1997

ASCE/PLD PINS Task Group -Jay Schrock

Pipe Rehabilitation Council (PRc) Symposia

Test Data-WRc and Utah State University
“Fully Deteriorated” Rehab Design

Design Equation (from AWWA C950/M45)-The Luscher Equation

\[ q_t = \frac{(C/N)}{32R_w B'E_s'(E_L I/D^3)}^{1/2} \quad \text{(ASTM F 1216)} \]

The equation, as originally developed by Luscher in 1966 was Subject to the following limiting assumptions:
1. Circular-symmetric geometry (C=1)
2. Uniform radial pressure \( q_t \)
3. Deflection resisted by soil modeled as identical discreet springs Uniformly distributed around the pipe
4. \( R_w = 1 \)
5. Experimental data only for very high SDR (200-500) low stiffness tubes (PS < 1).
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“If soil migration into the pipe has been limited and soil voids adjacent to the pipe are localized,..., Insituform design techniques are applicable.”

“...adequate soil side support is essential to stand-alone, flexible pipe design.”

“Typical values of Es’ are 700 to 1500 psi”

Insituform Design Guide
Section on “Fully Deteriorated” Design

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Soil Support "Enhancement"

\[ H_s = 25', \ H_w = 20', \ E_l = 125000, \ \mu = 0.3 \]
\[ w = 120 \text{pcf} \]
\[ E_s' = 3000 \]
\[ E_s' = 2000 \]
\[ E_s' = 1000 \]
\[ E_s' = 500 \]
\[ K = 7 \]
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Soil Support "Enhancement"

$H_s=25'$, $H_w=10'$, $EL=125,000$, $\mu=0.3$, $w=120$pcf

$E_s'=3000$

$E_s'=2000$

$E_s'=1000$

$E_s'=500$

$K=7$

SDR (D/t)
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Utah State University Soil Cell Test 1993

UNLINED PIPE
Unlined pipe is no longer serviceable.

DANBY LINED PIPE
At nineteen percent deflection, pipe was still serviceable.
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Utah State Univ.
1993 Soil Cell Test

Strains in Danby Liner
(Tension +)

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Clearly, the soil load transferred to the liner by the cracked concrete pipe is not uniformly distributed around the liner.
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Soil Compaction Effect

- GIP Lined PS=195 psi
- Unlined Es'=381 psi PS=202 psi
- Unlined Es'=228 psi PS=139 psi

Soil Cell Test Utah State Univ. 1988 & 1993

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Modified Iowa Deflection Formula

$$\frac{Y}{D} = \frac{LKP}{(8EI/D^3 + 0.061E_s')}, \ L=1, \ K=0.1$$

Slope of Load (P) Vs Deflection Line = Stiffness

$$\frac{dP}{d\theta} = \frac{80EI/D^3 + 0.61E_s'}{\theta}$$
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For GIP USU Test Data \( t = 0.50'' \), \( \text{OD} = 28'' \)

Unlined Slope = 20 ksf = 139 psi = .61 \( E'_s \); \( E'_s = 228 \) psi

Lined Slope = 28 ksf = 195 psi; \( 80EI/D^3 = 56 \) psi

\[
EI = 14,558 \text{ psi} \quad L = 1, \quad K = 0.1
\]

Laboratory ASTM D 790 Test of PVC/Grout Beam
\[
EI = 14,242 \text{ psi}
\]

Clearly Consistent Values
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Soil Compaction Effect

CIPP Line
PS=303 psi
Es' = 331 psi

Unlined
PS=202 psi

Unlined
Es' = 228 psi
PS=139 psi

Vertical Deflection (%)

Soil Cell Test
Utah State Univ.
1988 & 1993

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From USU test data it is clear that deflection limit will occur before buckling. In fact no indication of buckling was observed.
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For CIPP USU Test Data (t = 0.83”, OD = 30”)

Unlined Slope = 29 ksf = 202 psi = 0.61 E’ s ; E’ s = 331 psi

Lined Slope = 43.6 ksf = 303 psi; 80EI/D^3 = 101 psi

E = 665,594 psi      L = 1, K = 0.1

Probably high by a factor of 1.5 to 2
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If assumed soil support is present, the host pipe-soil structure dominates the structural response to the soil load.

\[
\frac{dP}{d\theta} = \frac{80EI}{D^3} + 0.61 E_s' \\
= 1.49PS + 0.61 E_s' \\
\text{For } E_s' = 700, \text{ SDR=}35, E=125,000 \\
= 21 + 427
\]
Conclusions

Test Data Does Not Support Buckling As Failure State

If Soil Support Required by Buckling Design Exist, Most Rigid Pipes Would Benefit Little, Structurally, From Liner

Liners Add Stiffness But Are Less Influential Than Soil Modulus
Conclusions

Flexible Liner Design Should Be Based On Adding Stiffness OR Hydrostatic Pressure

More Testing & FEA Modeling Is Needed To Determine Relationship Between Soil Modulus and Stiffness Added by Liner

The ASCE PINS Task Group On Rehab Design Should Recommend Changes In "Fully Deteriorated" Design